On-Road Motor Vehicle Activity Data

Volume I - Bus Population and Activity Pattern

Final Report

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ABSTRACT

The objectives of this study were threefold: (1) to develop county-specific estimates of the transit bus fleet and vehicle miles of travel (VMT) ; (2) to develop county-specific estimates of the school bus fleet and VMT; and (3) to determine representative driving patterns of transit buses and school buses. For transit buses, the fleet and activity data compiled by the Federal Transit Administration (FTA) and the American Public Transit Association (APTA) were obtained and analyzed. A supplemental manufacturer survey was conducted to obtain bus specification data, which were then used to develop a regression relationship between bus length and gross vehicle weight for buses listed in the FTA and APTA databases. In the base year of 1990, 8631 active transit buses were operated in the state and were driven 311 million miles or 36,000 mi/y per vehicle. These statewide fleet and VMT figures were then allocated to each ARB weight class and each county using the regression relationship and county allocation scheme developed under this study. For school buses, the California Highway Patrol (CHP) conducts an annual safety survey on every carrier or terminal in the state. Summary statistics of this bus safety inspection data were found to be the most complete and useful data source for estimating school bus population and annual VMT. To supplement the CHP school bus data, a public school survey for all school districts and a contractor survey for 8 major school bus contractors were conducted. Results of the two surveys provided general usage pattern data and detailed fleet characterization data such as model year, bus length, and annual mileage accumulation rate. These survey results and U.S.Census student enrollment statistics were used to develop a methodology for disaggregating the CHP school bus data into each ARB weight class and fuel type , and to each county. Statewide, 23,900 school buses were operated and driven 317 million miles or 13,000 mi/y per vehicle. Diesel buses account for a great majority of the statewide bus population (81%) and VMT (84%). Finally, driving patters of transit buses and school buses in Southern California were studied by following buses for about 30 minutes each with datalogger-equipped chase cars. A total of 210 bus routes were followed by chase vehicles to characterize bus driving patterns during weekday peak hours (6-9 AM and 3-6 PM in local prevailing time), weekday off-peak hours, Saturday, and Sunday for transit buses, and for school buses during weekday morning and weekday afternoon. Driving patterns were determined in three area types: urbanized, small urban, and rural. The driving pattern data acquired by the chase car study were analyzed and compared with the driving cycle data used in the Federal Test Procedure (FTP). It was found that transit buses idled more frequently and in longer duration than the FTP cycle. Although the overall trip speeds were about the same as the FTP's, their average driving speeds were considerably higher than the FTP: 20.7 mph vs 17.9 mph. A large time fraction spent in idling -- about 30% of total trip duration -- was common to both transit buses and school buses.

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GLOSSARY OF TERMS

APTA	American Public Transit Association
ARB	California Air Resources Board
CALTRANS	California Department of Transportation
CHP	California Highway Patrol
CSBCA	California School Bus Contractors Association
EMFAC	ARB's emission factor model for motor vehicles
DMV	Department of Motor Vehicles
FTA	Federal Transit Administration
GVW	Gross Vehicle Weight
GVWR	Gross Vehicle Weight Rating
HDV	Heavy-Duty Vehicle
HHDV	Heavy Heavy-Duty Vehicle
LDT	Light-Duty Truck
LHDV	Light Heavy-Duty Vehicle
MAR	Annual Mileage Accrual Rate
MDT	Medium-Duty Truck
MHDV	Medium Heavy-Duty Vehicle
MTD	Metropolitan Transit District
NA	Not Available
OMNI	Transit Operator in San Bernardino County
R	Rural Area
RT	Rural Transit
RTA	Riverside Transit Agency
RTD	Rapid Transit District
S	Small Urban Area
SB	School Bus
SCAB	South Coast Air Basin
SCAG	Southern California Association of Governments
SCAT	South Coast Area Transit in Ventura County
SCRTD	Southern California Rapid Transit District
TA	Transit Agency
TB	Transit Bus
TD	Transit District
TG	Thomas Guides Street Atlas
TS	Transit System
TYPE I	Large school buses designed to carry more than 16 passengers
TYPE II	Small school buses designed to carry not more than 16 passengers
U	Urbanized
UMTA	Urban Mass Transportation Administration
VIN	Vehicle Identification Number
VMT	Vehicle Miles of Travel
VRC	Valley Research Corporation
WD	Weekday
WE	Weekend

1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Buses are distinguished from other motor vehicles by their unique body style and usage patterns. The California Air Resources Board's (ARB's) emission factor model, EMFAC, treats buses as a separate source category from many body types found in motor vehicles. However, EMFAC provides the emission factors only for "urban diesel buses". Furthermore, the bus emission factors are determined for the same test driving cycle as that of heavy-duty trucks despite the buses' unique driving patterns.

A number of complicating factors call the current modeling of emissions from urban buses into question. For example, there are gasoline-fueled buses as well as diesel buses. There are more school buses than urban transit buses. Smaller buses are more likely to be termed as "modified vans", and tend to be driven less per vehicle than full-size buses. Both the usage and driving pattern of school buses seem to differ from those of transit buses. In summary, neither the population nor use pattern of buses are well understood at present. Therefore the objectives of this study were to:

- Estimate the statewide populations of transit buses and school buses;
- Estimate the statewide vehicle miles of travel (VMT) for transit buses and school buses;
- Develop a methodology to estimate bus populations and VMT at the county level;
- Determine bus VMT-by-speed distributions for transit buses and school buses;

To accomplish these objectives, Valley Research Corporation (VRC) conducted a special school bus survey, gathered and analyzed transit bus fleet and activity data, designed and implemented a chase car survey on bus driving patterns, and developed a methodology for estimating bus population and activity at the county level. A summary of findings and conclusions obtained from the present study is presented in the next subsection while detailed discussions of the study method used and the findings and conclusions arrived at for each study objective are made in the major sections that follow.

1.2 SUMMARY OF FINDINGS

The word "bus" is commonly used to refer to a vehicle that carries multiple people and operates on a schedule. However, there are many types of buses and bus operations that serve functions similar to those of non-bus vehicles such as taxis,limousines and "van pool" vans. Most buses are large in size, carrying 20 passengers or more. In recent years, smaller buses are increasingly used, carrying fewer passengers and operating on a demand-response basis instead of a fixed schedule. To clarify the meaning of the word "bus" used in this report, a few definitions of "buses" are given in Table 1-1. The terms motorbus and van are used to refer respectively to large and small transit buses while Type I and Type II buses are used to refer to large and small school buses.

Specifically, the Federal Transit Administration (FTA) defines a motorbus as a revenue vehicle operating on fixed routes and schedules on roadways. Motorbuses are divided into three classes: Class A (>35 seats), Class B (25-35 seats) and Class C (<25 seats). The FTA defines a van as a vehicle which has a typical seating capacity of 5 to 15 passengers and is classified as a van by vehicle manufacturers. A modified van that has undergone some structural changes, usually made to increase its size and particularly its height, has a typical seating capacity of 9 to 18.

The California Vehicle Code defines a Type I bus as a vehicle designed for carrying more than 16 passengers and the driver. A Type II bus is designed for carrying not more than 16 passengers and the driver, or manufactured on or after April 1, 1977, having a manufacturer's gross vehicle weight rating of 10,000 lbs or less, and designed for carrying not more than 20 passengers and the driver.

The following subsections summarize the findings made and the conclusions arrived at from analysis of the existing transit bus data, VRC-conducted school bus surveys, and the chase car study of both transit and school bus driving patterns.

Table 1-1. DEFINITIONS OF BUSES

Term	Definition	Typical Operation	Study Coverage
Transit Bus[a]	Revenue service vehicle classified as motorbus or van with mode of service operating on fixed routes and schedules on roadways or demand responsive service.	Public transit buses generally operating on scheduled routes in urban areas (e.g. SCRTD).	Included, except small transit operators.
General Public Paratransit Vehicle[b]	Any motor vehicle under the jurisdiction of a public transit system designed for carrying no more than 19 persons and the driver and operating as a dial-a-ride, subscription service, or route-deviated bus service. Does not include services for the handicapped or elderly.	Special services provided by transit systems which are not exclusively for the handicapped or elderly.	Partially included in transit, not strictly defined as buses.
Bus[b]	Any motor vehicle designed, used, or maintained for carrying more than 10 persons, including the driver, which is used to transport persons for compensation or profit, or is used by any nonprofit organization or group. Other vehicles will be considered buses if they exceed 15 persons, including the driver (except van pool vehicles).	Includes all bus operations. Provides additional definition of transit and charter type buses not provided elsewhere in the vehicle code.	Included, except small transit and most charter.
School Bus[b]	Any motor vehicle designed, used, or maintained for the transportation of any pupil at or below the 12th-grade level to or from public or private school activities except the following: an ordinary passenger vehicle, a passenger vehicle designed for carrying less than 10 passengers, a bus operated by a publicly owned or operated transit system, etc.	A "yellow" Type I or II bus operated by public or private schools, or contractors used for the transportation of school pupils to or from public or private school and their activities.	Included.
School Pupil Activity Bus[b]	Any motor vehicle other than a school bus used under a contractual agreement between a school and carrier to transport school pupils to or from a school activity or to off-highway locations where parents are present to accept the pupils.	Usually a Type I bus operated bus carrier which normally carries non-school passengers (i.e., charter buses) contracted to transport pupils to and from school activities.	Included.
Youth Bus[b]	Any bus other than a school bus designed for carrying not more than 16 persons and the driver, used to transport children directly from a public or private school to and from nonschool-related youth activities within 25 miles of the school.	Usually a Type II bus operated by a local organization (e.g., YMCA) which carries the children between schools and its organized local activities.	Included.
Farm Labor Vehicle[b]	Any motor vehicle designed, used, or maintained for the transportation of 9 or more farmworkers to or from a place of employment or employment-related activities. Does not include vehicles carrying only members of the immediate family, or operated under the authority of the State PUC or public transit system.	Vehicles carrying 9 or more farm workers which are not family vehicles and do not fall under other vehicle code definitions.	Not included. Not strictly defined as buses.

[a] "Glossary of Transit Terms," U.S. Department of Transportation, Urban Mass Transportation Administration, October 1991.

[b] "Motor Carrier Safety -- Excerpts for Title 13, California Code of Regulations," CHP 800 (Rev 5-91), Barclays Law Publishers, South San Francisco, California.

1.2.1 TRANSIT BUSES

- Transit bus population and activity levels in California were estimated for each of the four ARB weight classes (MDT, LHDV, MHDV, HHDV) using the Federal Transit Administration's (FTA's) bus activity data and the American Public Transit Association's (APTA's) bus directory.

- The FTA database and the APTA directory included all transit buses operated by medium to large transit agencies but excluded other buses such as farm labor vehicles, some general public paratransit vehicles (special small shuttle type services), and those operated by small transit agencies and privately operated transit services.

- A supplemental manufacturer survey was conducted to obtain bus specification data, which were then used to develop a regression relationship between bus length and gross vehicle weight (GVW) for buses listed in the FTA and APTA databases.

- Using the FTA database and the APTA directory, VRC identified 8,631 active transit buses operating in the state in 1990 and additional 740 inactive buses -- those used only for emergencies or remaining totally inactive during the year.

- Statewide transit bus VMT was estimated to be 311 million miles per year or 36,000 miles per year per active bus.

- Both buses and bus VMT were allocated first to correct ARB weight classes (i.e., MDT, LHDV, MHDV, HHDV) using the regression relationship, and then to fuel types and individual counties.

- Among the 12 categories defined by 4 weight classes and 3 fuel types, diesel-fueled HHDV buses account for by far the largest percentages in both bus population and VMT: 72 percent of the bus population and 76 percent of the annual VMT. Buses that run on fuels other than gasoline and diesel account for a rather modest share in both bus population and VMT: 6 percent of the population and 4 percent of the statewide bus VMT.

- Among the three fuel types, diesel buses dominate in the heavier weight classes of MHDV and HHDV while gasoline buses dominate only in the lightest class of MDT. Buses powered by other fuels are common in the MDT and LHDV classes.

1.2.2 SCHOOL BUSES

- The California Highway Patrol (CHP) conducts an annual safety inspection survey on every carrier or terminal of school buses in California. Summary statistics of this school bus safety inspection data were found to be the most complete and useful data source for estimating the school bus population and annual VMT in the state.

- To supplement the CHP school bus data, VRC conducted a public school survey for all public school districts in California and a contractor survey for 8 major school bus contractors. Results of the two surveys provided general usage pattern data and detailed fleet characterization data such as model year, bus length, bus model, manufacturer, and annual mileage accrual rate (MAR).

- An estimation methodology for school bus population and VMT by ARB weight class and fuel type was developed and applied to the CHP school bus data in conjunction with results of the two school bus surveys and student enrollment statistics in each county to generate county-specific estimates of school bus population and activity levels.

- The statewide school bus population is 23,900 buses, which is twice the transit bus population. Annual school bus VMT is 317 million vehicle miles statewide or 13,000 miles per bus.

- Diesel buses account for a great majority of the statewide bus population (81%) and VMT (84%). Gasoline buses comprise most of the remaining population and VMT, leaving practically none for other fuel buses.

- HHDVs weighing over 33,000 pound GVW account for over half of the statewide bus population and VMT while LHDVs weighing less than 14,000 pounds GVW account for about a third of the population and VMT.

- For school buses, mileage accrual rates are higher for LHDV buses (16,000 mi/y) than for HHDV buses (12,500 mi/y). Contractor buses exhibit considerably higher accrual rates (19,000) than either public school buses (13,000) or private school buses (9,200).

- The median age of contractor buses is considerably less than public school buses (4 years vs 11 years). For both contractor and public school buses, the mileage accrual rate does not decrease much with vehicle age, in contrast to automobiles. Buses are typically retired or rebuilt when they become unfit for regular service.

- School buses are driven predominantly on weekdays (98%), on urban surface streets (51-76%), and for home-to-school trips (68-74%). Deadhead miles account for 21% of total VMT for public school buses and 11% for contractor buses. Activity trips account for about 10% of VMT for both public school and contractor buses.

1.2.3 BUS DRIVING PATTERNS

- Driving patterns of transit buses and school buses in Southern California were studied by following buses for about 30 minutes each with datalogger-equipped chase cars.

- The datalogger used in each chase car was designed to record, for each bus chase trip, the date, the time, sequential trip number, trip duration, trip length, the number of idling events and cumulative duration for three ranges of idling duration, and travel time spent in each element of a speed-acceleration matrix consisting of 12 speed ranges with 5 mph increment each and 5 acceleration ranges.

- A total of 210 bus routes were followed by chase vehicles to characterize bus driving patterns during weekday peak hours (6-9 AM and 3-6 PM in local prevailing time), weekday off-peak hours, Saturday, and Sunday for transit buses, and for school buses during weekday morning and weekday afternoon. Driving patterns were determined in three area types: urbanized, small urban, and rural.

- The driving pattern data acquired by the chase car study were analyzed and compared with the driving cycle data used in the Federal Test Procedure (FTP). Dissimilarities were found between the FTP cycle and both transit bus driving patterns and school bus driving patterns.

- Transit buses idle more frequently and in longer duration than the FTP cycle. Although the overall trip speeds are about the same as the FTP's, their average driving speeds are considerably higher than the FTP: 20.7 mph vs 17.9 mph.

- A large time fraction spent in idling -- about 30% of total trip duration -- is common to both transit buses and school buses. The numbers of service stops and idling events are 15-16 and 31-32 respectively for transit buses on weekday, and for school buses, 3.5-4 and 21-23 respectively.

- The school bus driving patterns varied from urban areas to rural areas. Both the average trip speed and driving speed for "urbanized" and "small urban" areas are much lower than those of rural areas: 16-17 mph and 23-24 mph in urban areas vs. 23-27 mph and 29-33 mph.

- Speed profiles of the FTP cycle and the bus driving patterns were determined by converting time fractions in speed bins to VMT fractions in speed bins. While the speed profile of the FTP cycle exhibits a strong bimodal distribution having the first peak in the 25-29 mph range and the second peak in the 50-54 mph range, the actual bus driving patterns are either unimodal (for transit buses) or weak bimodal (for school buses).

2.0 TRANSIT BUS POPULATION AND ACTIVITY LEVELS

2.1 DATA SOURCES

The goals of this task were to develop a statewide inventory of buses and bus activities as measured in vehicle miles of travel (VMT) for each transit operator in California and to allocate the inventory to the county and air basin level. This was accomplished through gathering, reviewing, and compiling the currently available data from several transit bus data source agencies without resorting to any new data collection effort. Table 2-1 shows the agency-provided estimates for statewide bus population and VMT versus the estimates generated under this study. The present study probably underestimated transit buses and their activity levels because the primary data sources, the FTA* and APTA*, covered only large to medium (>5 buses) public transit agencies. Additional buses (included in the Caltrans and DMV estimates but not the present study) are farm labor vehicles, some paratransit vehicles (special shuttle type services), and those operated by small transit agencies and privately operated transit companies.

Table 2-2 shows the ARB and FHwA* weight classes. In this study bus population and VMT are estimated for four ARB weight classes: MDT (6,001-8,500 lbs. GVW), LHDV (8,501-14,000 lbs.), MHDV (14,001-33,000 lbs.) and HHDV (>33,000 lbs.).

VRC gathered various directories and bus statistics from data source agencies such as the U.S. Department of Transportation's Federal Transit Administration (previously UMTA*), Caltrans, and American Public Transit Association. Table 2-3 shows the coverage of each data source. Estimates for transit busing came primarily from the FTA data, which were partially supplemented by a few additional fleet operators listed in the APTA directory. The data gathered for each operator included: number of active and inactive buses for each bus type; bus fleet data including manufacturer, model, year built and re-built, size (seating or length), engine type, fuel type; VMT for each bus type for lifetime and year of record; and fleet VMT proportions for each county (if more than one in service area).

The FTA databases and accompanying publications provide bus population and VMT information for most medium to large transit fleets. Each fleet summary contains the following information: year built, body manufacturer, model, seating capacity, standing capacity, type of fuel, type of engine, number of vehicles owned and leased, number of vehicles used in active service, number used in peak service, and mode of service (motor bus vs demand response). FTA data are representative of any transit system fiscal year ending in 1990.

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* The meanings of these acronyms and abbreviations are given in the "Glossary of Terms."

Table 2-1. VARIOUS ESTIMATES OF BUS POPULATION AND VMT

Source Agency	Bus Population			Annual VMT in Millions		
	Transit	School	Total	Transit	School	Total
Federal Transit Administration (FTA[1])	8,233			298		
Calif. Dept. of Transportation (Caltrans[2])	11,982			368		
Calif. Highway Patrol (CHP[3])		23,900			317	
Calif. Dept. of Motor Vehicles (DMV[4])			40,589			
This Study[5]	9,371 (8,631)	23,900	33,271	311	317	628

1. FTA (formerly UMTA) Section 15 Data for Fiscal Year Ending in 1990.
2. "Public Transportation Alternative Fuels - A Perspective for Small Transportation Operations," Calif. Dept. of Transportation (1992), Prepared by Booz-Allen & Hamilton.
3. CHP Annual School Bus Report for Calendar Year 1991.
4. DMV Bus Registration Totals for the 12 Month Period of June 1992 through May 1993, Prepared by Betty Stanfield of the DMV Registration Division.
5. The value in parenthesis indicates the number of actively used transit buses.

Table 2-2. ARB AND FHwA VEHICLE WEIGHT CLASSES

Gross Vehicle Weight	ARB Weight Class	FHwA Weight Class
1-6,000 lbs	LDT	Class I
6,001-8,500 lbs	MDT	Class IIA
8,501-10,000 lbs	LHDV	Class IIB
10,001-14,000 lbs	LHDV	Class III
14,001-16,000 lbs	MHDV	Class IV
16,001-19,500 lbs	MHDV	Class V
19,501-26,000 lbs	MHDV	Class VI
26,001-33,000 lbs	MHDV	Class VII
Over 33,000 lbs	HHDV	Class VIII

Table 2-3. LIST OF TRANSIT BUS DATA SOURCES

Data Source	Data Available
American Public Transit Association (APTA)	Fleet inventories of member transit operators w/o activity data.
California Department of Motor Vehicles (DMV)	Summary statistics of statewide bus populations.
California Department of Transportation (Caltrans)	Summary information gathered through statewide survey of a broad range of transit operators.
Federal Transit Administration (FTA)	Fleet inventories and activities of larger transit operators receiving federal funding.
Transit Operators	Telephone contact for clarifying information on their operations.

The APTA directory entitled "1992 Transit Passenger Fleet Inventory" contains transit system passenger vehicle fleet information for 44 motor bus fleets in California. Each system inventory is representative of Jan. 1, 1992. Each fleet summary contains the following information: year built, year rehabbed, body manufacturer, model, seats, length, width, type of fuel, type of engine, number of vehicles owned and leased, number of vehicles used in active service, number used in peak service, and mode of service (motor bus vs demand response). The APTA directory provides very good and thorough data for the California transit system's bus population and age distribution, but provides no activity information other than mode of service for the different bus types.

For purposes of classifying buses reported in the FTA and APTA databases into ARB vehicle weight classes, a limited manufacturer survey was conducted to gather bus specification data from about two dozen manufacturers. These specification data were used to develop a regression relationship between bus length and gross vehicle weight (GVW).

2.2 ESTIMATES OF TRANSIT BUS POPULATION AND VMT

Data records in FTA and APTA databases are fairly comprehensive in describing transit bus fleet composition. Data items in each record include year built, body manufacturer, model, seats, length (in APTA only), number of vehicles by ownership, mode of service, and annual VMT (in FTA only). To derive county-specific estimates of transit bus population and activity from these databases required a data gathering effort and the development of an estimation methodology, as well as the merger of the two databases.

Figure 2-1 shows the methodology used to estimate county-specific bus population and activity levels for each ARB weight class and each fuel type. Since FTA data do not include bus length, length information found in APTA data records was merged with seating capacity of the corresponding FTA data records. Corresponding records were determined manually by reading all descriptive data items in the two databases for each model year bus fleet of the same transit operator. A total of 81 unique bus models (excluding articulated buses) were identified and used to develop a regression relationship between seating capacity and total bus length. Figure 2-2 shows the regression relationship between seats and bus length, which is significant at the 99% confidence level.

Since neither database contains any information on gross vehicle weights of individual buses, VRC gathered bus specification data from about two dozen bus body manufacturers. These data included gross vehicle wight rating (GVWR) and total length for each bus model. A total of 39 distinct bus models with specifications were identified and used to develop a regression relationship between bus length and GVWR. Figure 2-3 shows the regression equation

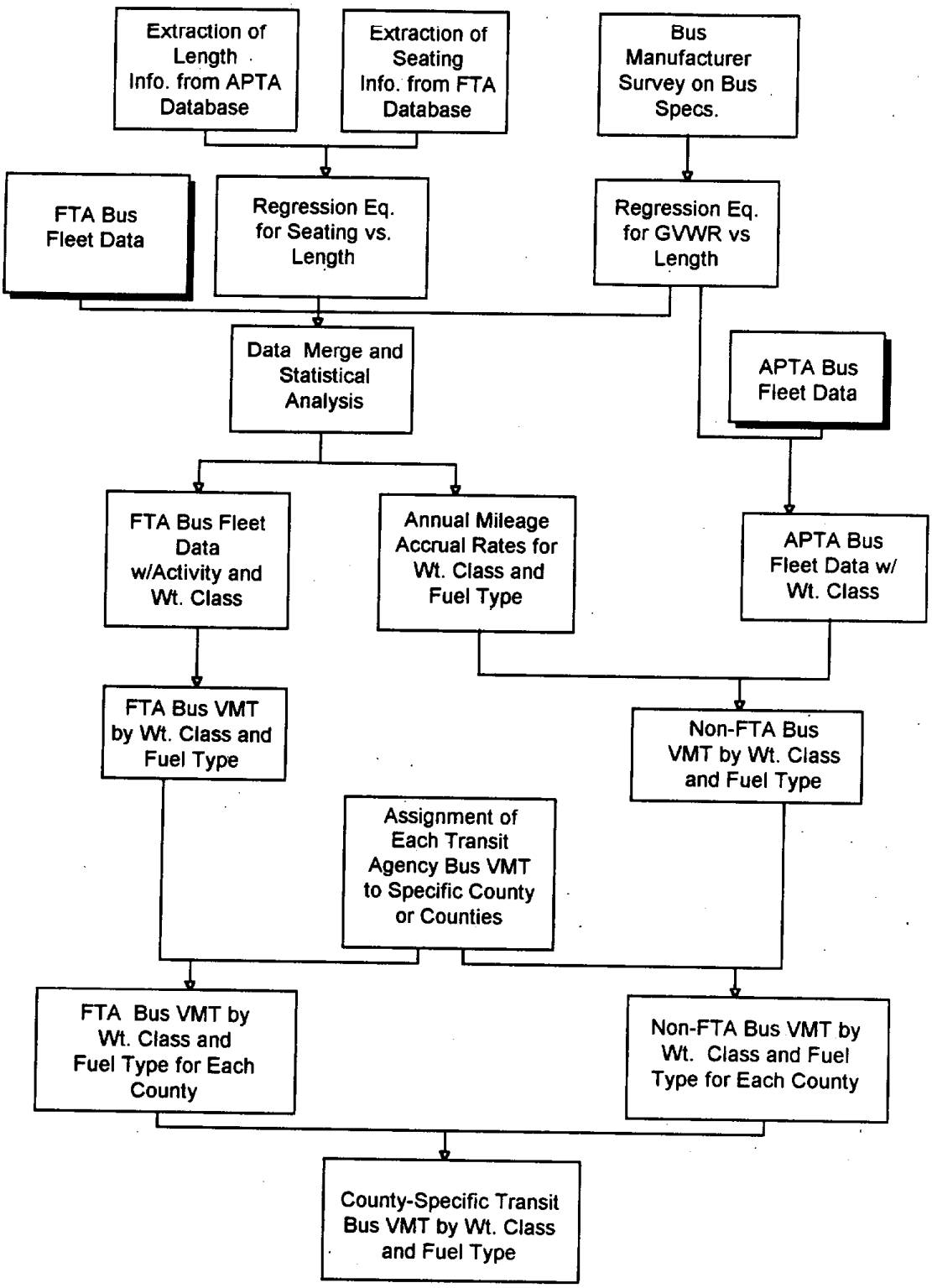

Figure 2-1. Methodology Used for Developing County-Specific Estimates of Transit Bus Population and VMT by Weight Class and Fuel Type

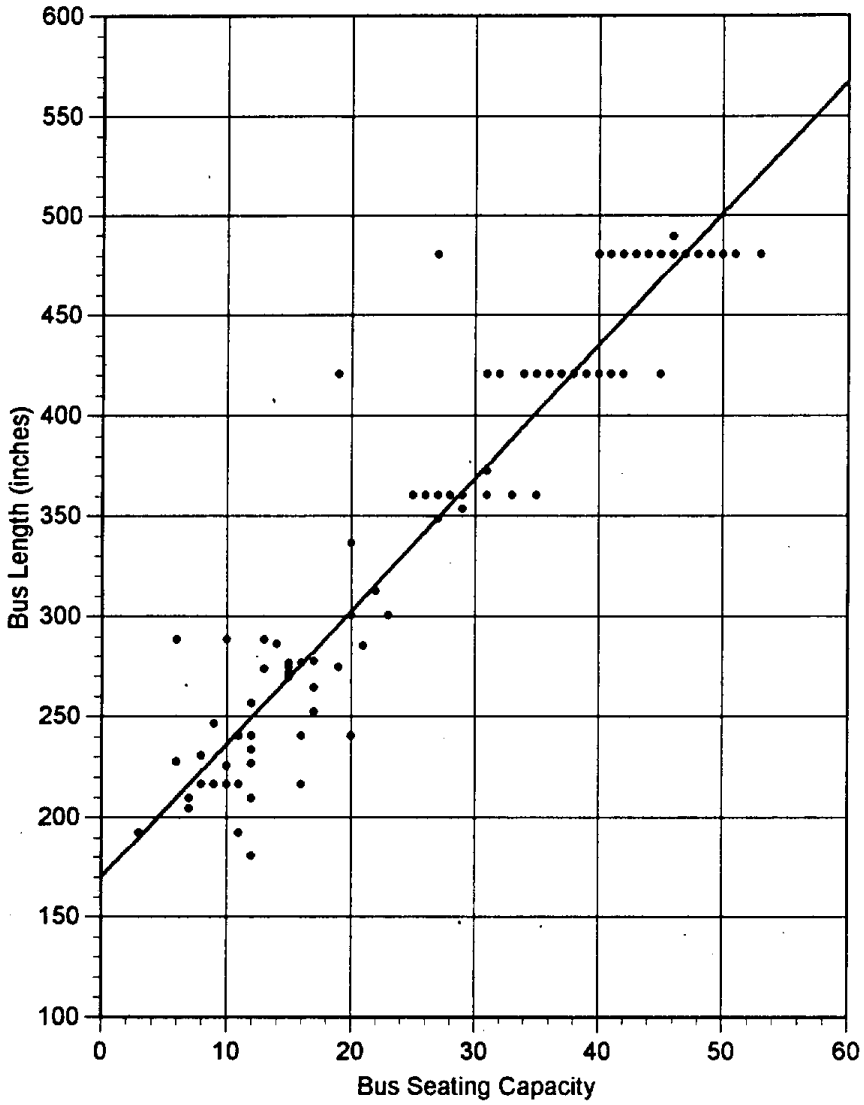

Figure 2-2. Relationship between Bus Seating and Bus Length (n=81, Length(inches) = 170+6.6*Seating)

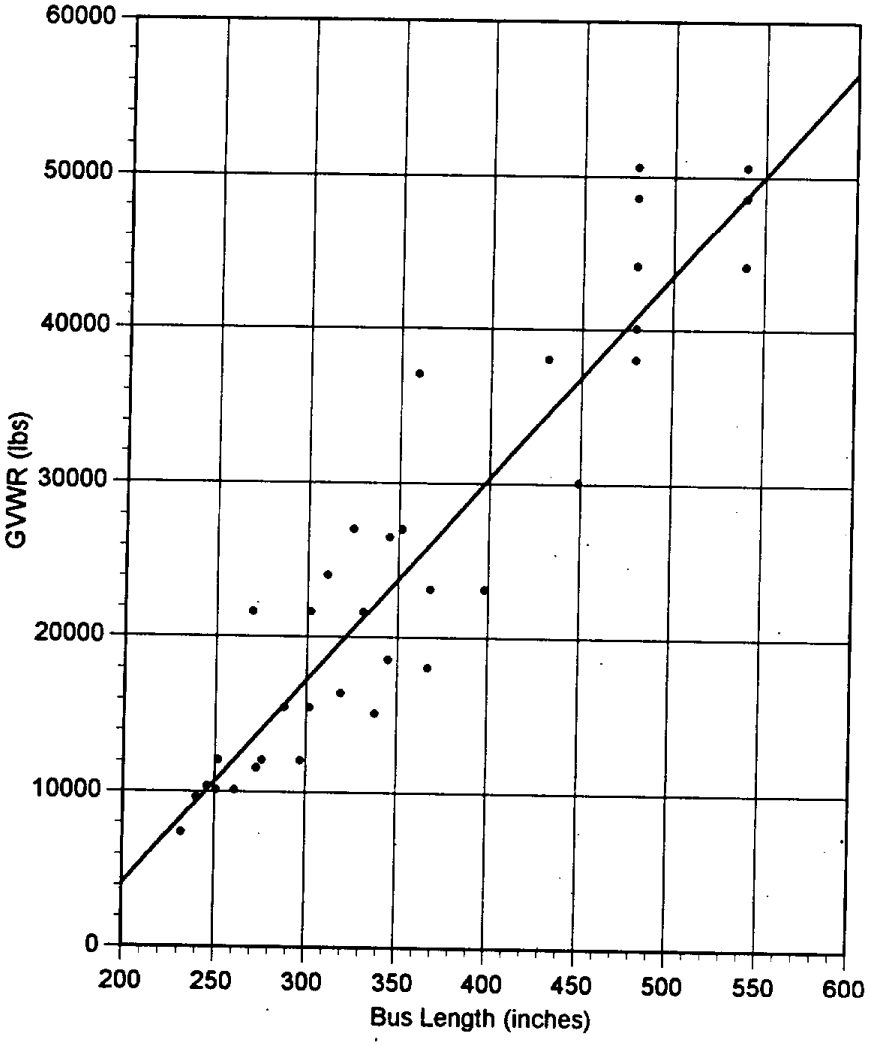

Figure 2-3. Relationship between Bus Length and GVWR (n=39, GVWR(lbs)= -22090+131*Length(inches))

regression relationship between bus length and GVWR, which is also significant at the 99% confidence level.

The two regression relationships described above were then applied to each FTA and APTA data record to determine the appropriate ARB weight class for each bus. In deriving both regression relationships, articulated buses -- those consisting of a power unit and trailer(s) -- were excluded because of the relatively light weight in relation to the great length. All articulated buses were considered to be heavy-HDV or HHDV weighing over 33,000 pounds GVW.

Although FTA data records contain bus activity information, APTA data records for about 400 additionally identified buses have no activity information. To incorporate these additional APTA data into the current database, annual mileage accrual rate were determined from complete FTA records with activity data for four ARB weight classes (i.e., MDT, LHDV, MHDV, and HHDV) and three fuel types (i.e., gasoline, diesel, and other). Table 2-4 shows the annual mileage accrual rates. It indicates that diesel buses tend to accrue more miles than gasoline buses and that heavier buses tend to accrue greater miles than lighter buses, Buses powered by other fuels accrue mileage at annual rates comparable to those of gasoline-powered buses.

By applying the mileage accrual rates generated from FTA data to APTA records, activity levels of about 400 additional buses were estimated as well as those of 8233 buses in the FTA database. Thus, a total of 8631 buses found in the FTA and APTA databases were characterized as to their activities, weight classes and fuel types.

The final step of the methodology of estimating transit bus population and activity was to allocate these buses to specific counties where their activity takes place. Table 2-5 lists all transit bus agencies used for this study (see Appendix A for address list). The FTA database provided 50 transit agencies while the APTA database yielded an additional 12 agencies. A few transit agencies provide their services to more than one county. VRC contacted these multi-county operators -- which included SCRTD, Alameda-Contra Costa Transit District, and Hub Area Transit Authority -- to obtain their approximate VMT-based service proportion among each county of service.

Resulting estimates of statewide active bus population and annual VMT by weight class and fuel type are presented in Tables 2-6a and 2-6b. Table 2-6a shows the number of active buses and their VMT operated by 50 FTA-included transit agencies only. Table 2-6b shows the same operated by 50 FTA- and 12 APTA-included transit agencies in California. There are 8631 active buses and 740 inactive buses -- those used only for emergency or remained totally inactive

Table 2-4. ANNUAL MILEAGE ACCRUAL RATE BY FUEL TYPE AND WEIGHT CLASS (using FTA data)

GVWR Class	Fuel Type: Diesel n	Diesel MAR	Gasoline n	Gasoline MAR	Other n	Other MAR
MDT	9	27,300	116	15,100	80	16,000
LHDV	4	44,800	23	11,200	25	22,800
MHDV	1304	34,700	126	32,800	58	22,100
HHDV	6110	38,400	0	Unknown	378	21,300

Note: n = sample size
MAR = mileage accrual rate per vehicle per year

Table 2-5. TRANSIT OPERATORS BY DATA SOURCE AS USED IN TRANSIT BUS POPULATION AND VMT ESTIMATES

Transit Name	Counties Serviced
Data Source: APTA*	
Arcata & Mad River TS*	Humboldt
Chula Vista Transit	San Diego
City of Whittier	Los Angeles
County of San Diego	San Diego
Foothill Transit	Los Angeles
Humboldt County TA*	Humboldt
Kings Area RT*	Kings
National City Transit	San Diego
Ridgecrest Area Transit	Kern
San Luis Transit	San Luis Obispo
Tulare County Transit	Tulare
University TS	Yolo
Data Source: FTA*	
Alameda-Contra Costa TD*	Alameda, Contra Costa
Arcadia Dial-A-Ride	Los Angeles
Bakrsfld-Golden Empire TD	Kern
Central Contra Costa TA	Contra Costa
City of Chico TS	Butte
City of Commerce	Los Angeles
City of Corona	Riverside
City of Fairfield	Solano
City of La Mirada Transit	Los Angeles
City of Merced TS	Merced
City of Santa Rosa	Sonoma
City of Simi Valley TS	Ventura
City of Torrance TS	Los Angeles
City of Visalia	Tulare
Culver City Muni Bus Line	Los Angeles
Fresno TS	Fresno
Gardena-Municipal Bus	Los Angeles
Hub Area TA	Sutter, Yuba
Laguna Beach Muni Transit	Orange

* See "Glossary of Terms" for the meaning.

Table 2-5. TRANSIT OPERATORS BY DATA SOURCE AS USED IN TRANSIT BUS POPULATION AND VMT ESTIMATES (Cont.)

Transit Name	Counties Serviced
Data Source: FTA (cont.)	
Long Beach Public Trans	Los Angeles
Los Angeles Cnty Trans Co	Los Angeles
Los Angeles-SCRTD*	Los Angeles
Modesto Intracity Transit	Stanislaus
Montebello Muni Bus Lines	Los Angeles
N San Diego Transit Dev	San Diego
Napa City Bus	Napa
Norwalk TS*	Los Angeles
Orange County TD*	Orange
Oxnard-S Coast Area Tran	Ventura
Redding Area Bus Auth	Shasta
Riverside Specl Trans Svc	Riverside
Riverside Transit Agency	Riverside
Sacramento RTD*	Sacramento
San Bern-OMNITRANS*	San Bernardino
San Diego TS	San Diego
San Fran-Golden Gate TD*	San Francisco
San Mateo County District	San Mateo
Santa Barbara MTD*	Santa Barbara
Santa Clara County TD	Santa Clara
Santa Cruz MTD	Santa Cruz
Santa Maria Area Transit	Santa Barbara
Santa Monica Muni Bus	Los Angeles
Sonoma County Transit	Sonoma
Stockton MTD	San Joaquin
SunLine Transit Agency	Riverside
Vallejo Transit	Solano
Woodland-Yolobus	Yolo

* See "Glossary of Terms" for the meaning.

Table 2-6a. STATEWIDE ESTIMATE OF ACTIVE BUS POPULATION AND ANNUAL VMT BY WEIGHT CLASS AND FUEL TYPE (using **FTA data only**)

GVWR	Diesel		Gasoline		Other		Total	
	Number	VMT*	Number	VMT*	Number	VMT*	Number	VMT*
MDT	9	246	116	1748	80	1281	205	3275
LHDV	4	179	23	258	25	570	52	1007
MHDV	1304	45228	126	4130	58	1284	1488	50642
HHDV	6110	234635	0	0	378	8045	6488	242680
Total	7427	280288	265	6136	541	11180	8233	297604

* In 1000 vehicle miles of travel

Table 2-6b. STATEWIDE ESTIMATE OF BUS POPULATION AND ANNUAL VMT BY WEIGHT CLASS AND FUEL TYPE (using **FTA and APTA data**)

GVWR	Diesel		Gasoline		Other		Total	
	Number	VMT*	Number	VMT*	Number	VMT*	Number	VMT*
MDT	13	355	150	2260	82	1313	245	3928
LHDV	6	269	26	292	25	570	57	1131
MHDV	1531	53101	150	4917	60	1328	1741	59346
HHDV	6210	238589	0	0	378	8045	6588	246634
Total	7760	292314	326	7469	545	11256	8631	311039

* In 1000 vehicle miles of travel

during the year. Since inactive buses were expected to contribute very little to statewide bus VMT, all VMT estimates were made only for active buses. Statewide transit bus VMT was estimated to be 311 million miles per year or 36,000 miles per year per active bus.

Among the 12 categories defined by 4 weight classes and 3 fuel types, diesel-powered HHDV buses account for by far the largest percentages in both bus population and activity: 72 percent of the bus population and 76 percent of the annual VMT. Buses run on other fuel (i.e., non-gasoline and non-diesel) account for rather modest shares in both bus population and activity: 6 percent of the population and 4 percent of the statewide bus VMT.

Tables 2-7a and 2-7b show the estimated number of active diesel and gasoline buses, respectively, by weight class at the county level. Table 2-7c shows the total population estimate for all fuel types by weight class at the county level. Table 2-8 shows the total VMT estimates for all fuel types by weight class at the county level. Los Angeles is the predominant county, primarily because of SCRTD.

Table 2-9 shows the relative importance of each of the three fuel types (gasoline, diesel, and other) in each weight class for the statewide bus population and annual VMT. Diesel buses dominate in the heavier weight classes of MHDV (14,000-33,000 pounds GVW) and HHDV (>33,000 pounds GVW) while gasoline buses dominate only in the lightest class of MDT (6,000-8,5000 pounds GVW). Buses powered by other fuels are common in MDT and LHDV (8,500-14,000 pounds GVW).

Any future updates of the current estimates of bus population and VMT can be made rather easily by following the methodology described above. The two databases, FTA and APTA, are updated annually and available in magnetic media and hard copies, respectively. Should the ARB consider such update efforts appropriate only for a major inventory update at every 5 or 10 years, the following simplified method may be used for an interim annual inventory update.

Figure 2-4 shows a scatter plot of state total transit revenue vehicle miles versus state total population for years, 1986 (fiscal year 1986-87 for revenue VMT) through 1990. As seen from the figure, the total revenue VMT is correlated well with the total population as:

$$\text{Total Revenue VMT} = -20.271 + 12.868 \times (\text{Total Population}) \qquad (2\text{-}1)$$

Equation (2-1) has $R^2 = .807$ for $n = 5$ which is found to be statistically significant at 90 percent confidence level. In the fiscal year 1989-90, transit bus VMT was found to be 87.4 percent of the total transit revenue VMT. By assuming that this percentage remains approximately the same, an annual update of transit bus VMT can be made by applying this percentage to the total revenue VMT calculated from Eq. (2-1).

Table 2-7a. ESTIMATED NUMBER OF ACTIVE DIESEL TRANSIT BUSES BY WEIGHT CLASS AT THE COUNTY LEVEL IN 1989/1990 (using FTA and APTA data)

County*	MDT	LHDV	MHDV	HHDV	Total
ALAMEDA	0	0	109	621	730
BUTTE	0	0	10	0	10
CONTRA COSTA	0	0	78	34	112
FRESNO	0	0	12	73	85
HUMBOLDT	0	2	11	10	23
KERN	8	0	56	7	69
KINGS	0	0	1	0	1
LOS ANGELES	0	0	349	2841	3190
MERCED	0	0	6	0	6
MONTEREY	0	0	5	47	52
NAPA	0	0	9	0	9
ORANGE	0	0	41	400	441
RIVERSIDE	2	0	23	69	94
SACRAMENTO	0	0	61	138	199
SAN BERNARDINO	0	0	34	41	75
SAN DIEGO	5	4	180	348	537
SAN FRANCISCO	0	0	41	753	794
SAN JOAQUIN	0	0	76	0	76
SAN LUIS OBISPO	0	0	6	0	6
SAN MATEO	0	0	79	249	328
SANTA BARBARA	0	0	40	34	74
SANTA CLARA	0	0	97	411	508
SANTA CRUZ	0	0	70	16	86
SHASTA	0	0	10	0	10
SOLANO	0	0	15	39	54
SONOMA	0	0	22	37	59
STANISLAUS	0	0	17	14	31
SUTTER	0	0	0	0	0
TULARE	0	0	12	0	12
VENTURA	0	0	32	7	39
YOLO	0	0	29	21	50
YUBA	0	0	0	0	0
TOTAL:	13	6	1531	6210	7760

* All unlisted counties have no transit buses according to the FTA and APTA data.

Table 2-7b. ESTIMATED NUMBER OF ACTIVE **GASOLINE** TRANSIT BUSES BY WEIGHT CLASS AT THE COUNTY LEVEL IN 1989/1990 (using FTA and APTA data)

County*	MDT	LHDV	MHDV	HHDV	Total
ALAMEDA	0	0	0	0	0
BUTTE	0	0	0	0	0
CONTRA COSTA	0	0	0	0	0
FRESNO	4	0	8	0	12
HUMBOLDT	1	1	0	0	2
KERN	2	0	1	0	3
KINGS	9	0	1	0	10
LOS ANGELES	29	15	16	0	60
MERCED	0	0	10	0	10
MONTEREY	3	0	0	0	3
NAPA	0	0	0	0	0
ORANGE	1	0	8	0	9
RIVERSIDE	24	7	20	0	51
SACRAMENTO	0	0	4	0	4
SAN BERNARDINO	49	0	39	0	88
SAN DIEGO	19	3	14	0	36
SAN FRANCISCO	0	0	0	0	0
SAN JOAQUIN	0	0	0	0	0
SAN LUIS OBISPO	0	0	1	0	1
SAN MATEO	0	0	0	0	0
SANTA BARBARA	0	0	6	0	6
SANTA CLARA	0	0	0	0	0
SANTA CRUZ	0	0	0	0	0
SHASTA	0	0	0	0	0
SOLANO	0	0	0	0	0
SONOMA	0	0	0	0	0
STANISLAUS	0	0	0	0	0
SUTTER	1	0	14	0	15
TULARE	8	0	4	0	12
VENTURA	0	0	0	0	0
YOLO	0	0	4	0	4
YUBA	0	0	0	0	0
TOTAL:	150	26	150	0	326

* All unlisted counties have no transit buses according to the FTA and APTA data.

Table 2-7c. ESTIMATED NUMBER OF ACTIVE TOTAL TRANSIT BUSES BY WEIGHT CLASS AT THE COUNTY LEVEL IN 1989/1990 (using FTA and APTA data)

County*	MDT	LHDV	MHDV	HHDV	Total
ALAMEDA	0	0	109	621	730
BUTTE	0	0	10	0	10
CONTRA COSTA	0	0	78	34	112
FRESNO	4	0	20	73	97
HUMBOLDT	1	3	11	10	25
KERN	8	0	57	7	72
KINGS	9	0	2	0	11
LOS ANGELES	31	15	365	2874	3285
MERCED	0	0	16	0	16
MONTEREY	3	0	5	47	55
NAPA	0	0	9	0	9
ORANGE	81	25	107	400	613
RIVERSIDE	26	7	43	69	145
SACRAMENTO	0	0	65	138	203
SAN BERNARDINO	49	0	73	41	163
SAN DIEGO	24	7	194	348	573
SAN FRANCISCO	0	0	41	1098	1139
SAN JOAQUIN	0	0	76	0	76
SAN LUIS OBISPO	0	0	9	0	9
SAN MATEO	0	0	79	249	328
SANTA BARBARA	0	0	46	34	80
SANTA CLARA	0	0	97	411	508
SANTA CRUZ	0	0	70	16	86
SHASTA	0	0	10	0	10
SOLANO	0	0	15	39	54
SONOMA	0	0	22	37	59
STANISLAUS	0	0	17	14	31
SUTTER	1	0	14	0	15
TULARE	8	0	16	0	24
VENTURA	0	0	32	7	39
YOLO	0	0	33	21	54
YUBA	0	0	0	0	0
TOTAL:	245	57	1741	6588	8631

* All unlisted counties have no transit buses according to the FTA and APTA data.

Table 2-8. ESTIMATED ANNUAL VMT FOR TRANSIT BUSES BY WEIGHT CLASS AT THE COUNTY LEVEL IN 1989/1990 (using FTA and APTA data)

County*	(All values in 1000 vehicle miles of travel) MDT	LHDV	MHDV	HHDV	Total
ALAMEDA	0	0	4089	17552	21641
BUTTE	0	0	287	0	287
CONTRA COSTA	0	0	3043	3710	6753
FRESNO	69	0	736	2587	3392
HUMBOLDT	15	101	382	384	881
KERN	161	0	2463	131	2756
KINGS	136	0	67	0	203
LOS ANGELES	496	232	11494	114643	126865
MERCED	0	0	1187	0	1187
MONTEREY	78	0	100	2466	2644
NAPA	0	0	274	0	274
ORANGE	1287	570	3110	17746	22713
RIVERSIDE	337	31	1315	3713	5396
SACRAMENTO	0	0	1909	6210	8119
SAN BERNARDINO	628	0	1908	1917	4453
SAN DIEGO	552	196	8013	16442	25204
SAN FRANCISCO	0	0	977	28397	29374
SAN JOAQUIN	0	0	2233	0	2233
SAN LUIS OBISPO	0	0	285	0	285
SAN MATEO	0	0	2288	7042	9330
SANTA BARBARA	0	0	1319	571	1890
SANTA CLARA	0	0	4255	18693	22948
SANTA CRUZ	0	0	3093	911	4004
SHASTA	0	0	487	0	487
SOLANO	0	0	444	837	1281
SONOMA	0	0	79	988	1067
STANISLAUS	0	0	532	659	1191
SUTTER	13	0	175	0	188
TULARE	144	0	451	0	595
VENTURA	0	0	1111	303	1414
YOLO	0	0	1065	731	1797
YUBA	12	0	174	0	186
TOTAL:	3929	1130	59346	246634	311039

* All unlisted counties have no transit buses according to the FTA and APTA data.

Table 2-9. FRACTIONAL DISTRIBUTIONS OF STATEWIDE BUS POPULATION AND VMT OVER FUEL TYPES FOR EACH WEIGHT CLASS (based on FTA and APTA data)

Weight Class	n	Fuel Type Diesel	Gasoline	Other	Total
Bus Population					
MDT	245	.053	.612	.335	1.00
LHDV	57	.105	.456	.439	1.00
MHDV	1741	.879	.086	.034	1.00
HHDV	6588	.943	.000	.057	1.00
Bus Annual VMT					
MDT	245	.091	.575	.334	1.00
LHDV	57	.238	.258	.504	1.00
MHDV	1741	.895	.083	.022	1.00
HHDV	6588	.967	.000	.033	1.00

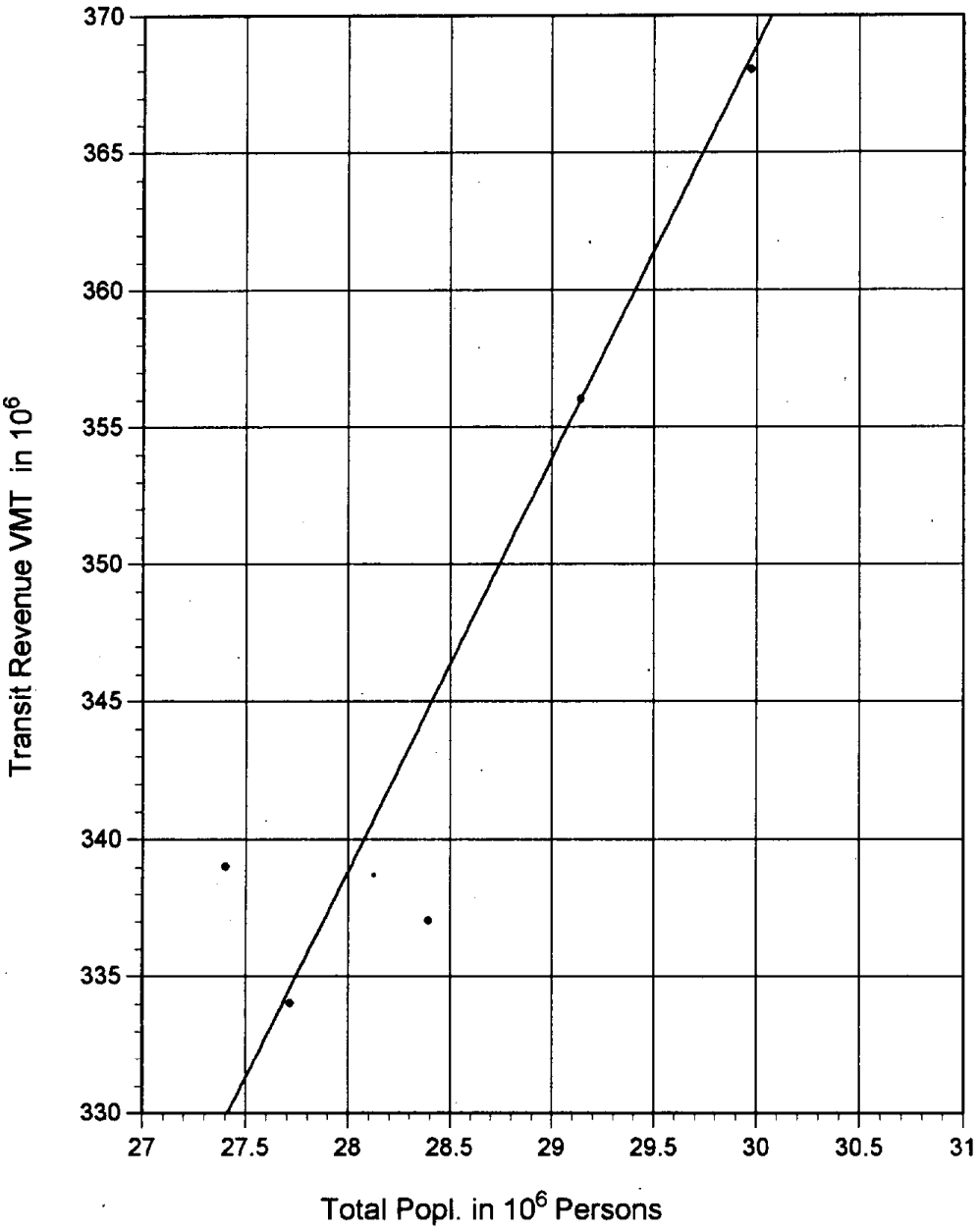

Figure 2-4. Total Transit Revenue Vehicle Miles Versus State Total Population (Source: Demographic Research Unit of the Department of Finance, and Transit Reporting Unit of the Office of State Controller)

3.0 SCHOOL BUS POPULATION AND USE PATTERN

3.1 SURVEY-GENERATED AND EXISTING DATA

The objective of this task was to estimate population and activity levels for California's school buses. The primary source of existing data used in this task was the California Highway Patrol (CHP) annual school bus safety inspection program. Under this program, CHP annually updates data on numbers of buses, use purposes, and odometer readings along with safety-related inspection items.

Two other state agencies were also contacted but were determined to be unable to provide useful data. The DMV maintains registration records for all motor vehicles in the state, but according to DMV staff their records are least complete for buses among the various vaheicle classes. The Department of Education recently conducted a school bus survey for the state's public schools but did not ask any questions regarding bus activities. Since neither of these agencies were able to provide data of the scope and quality required for the project, the division-level CHP data was used to provide the framework for further investigation.

Although the original school bus safety inspection data were kept in CHP's divisional offices and were not available for the present study, the CHP headquarters in Sacramento was able to provided a statistical summary of school bus population and activity levels for its eight Divisions (see Figure 3-1). The summary statistics include both number counts and annual VMT values for Type I ($\geq$ 16 passengers) and Type II ($<$ 16 passengers) buses owned by public school district, private schools, and bus contractors in each CHP Division. The statistics disaggregate buses not only into two size classes (i.e., Type I vs Type II) but also into three bus categories: school bus school activity bus, and youth bus. The latter two categories comprise only a small portion of the school bus population and appear to be operated by non-school organizations such as YMCA and charter services as well.

Because of the wide and complete coverage of school bus categories and school bus operators, the CHP school bus data were presumed to constitute the universe of all school buses in California. However, with only the data summary instead of original data records, use of the CHP school bus data is limited to framing the bus population and its annual VMT at the Division level. Therefore, VRC designed and implemented a school bus survey to gather additional data that would provide means to disaggregate the CHP school bus statistics into a vehicle age distribution, ARB weight classes, and county-specific estimates of bus population and activity.

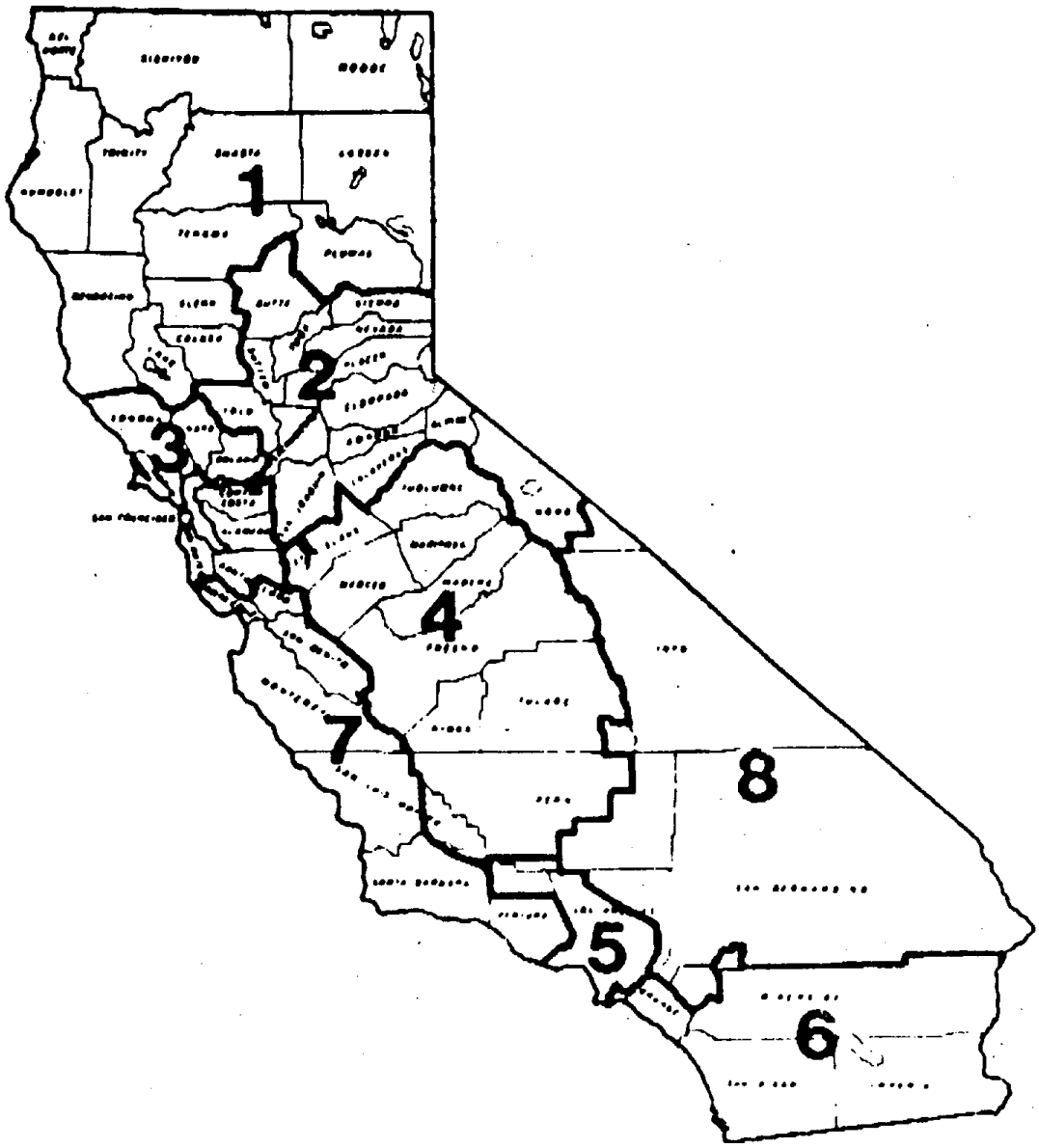

Figure 3-1. Geographical Boundaries of the CHP's Eight Divisions.

3.1.1 CHP DATA

The California Highway Patrol (CHP) has the authority to inspect motor vehicles for safety compliance. Based on this authority, the CHP inspects all school buses once a year regardless of ownership. Each CHP safety inspection is documented in two forms: the Safety Compliance Report (Form 343) which is designed to record safety information on each carrier or terminal; and Vehicle/Equipment Inspection Report (Form 343A) which is designed to record safety information on each vehicle.

A summary of the information reported in Form 343 is publicly available from MISTER (Management Information System of Terminal Evaluation Records) on magnetic tape. After acquiring and reviewing a MISTER data file, VRC concluded that although the MISTER file provided the fleet composition (Type I vs Type II) data and fleetwide VMT at each terminal, the data file was too complex to be used for the present study. Form 343A contains vehicle-specific data items such as VIN, odometer reading, fuel type, and make. Although the data contained in this form are not available through the MISTER data service, the hard copies kept in each CHP district can be made available for public review, but usually only a single report at a time. VRC concluded that gathering data through these reports would not be effective for this study either.

However, if future arrangements could be made between ARB and CHP to compile these data into an inventory database which is updated annually, then these reports would have great potential utility.

VRC contacted the Commercial & Technical Services Section at the CHP headquarters in Sacramento and found more usable summary statistics of the numbers of buses by ownership and bus type and annual accumulated miles of those buses for each of the 8 CHP divisions in California. Since CHP data are inclusive of all school bus carriers (i.e., private schools and contractors as well as public schools), the CHP statewide school bus population and VMT estimates were considered to provide the frames of school bus population and their annual activity levels at the Division level. Table 3-1 shows the statewide school bus population and their annual activity levels for four categories: public school, contractor, private school, and youth & activity bus. The table indicates that public schools and bus contractors account for the bulk of school bus activities in the state.

VRC also gathered county-specific CHP data from two CHP divisions. These were used to check the accuracy of our bus population and VMT estimates at the county level that were arrived at under this study.

Table 3-1. STATEWIDE SCHOOL BUS POPULATION AND ANNUAL VMT BY BUS CATEGORY IN 1991 (from CHP Statewide Statistics)

Bus Category	School Buses		Annual VMT	
	Number	Percent	1000 Miles	Percent
Public School	14,627	61	178,802	56
Contractor	6,871	29	119,863	38
Private School	1,029	4	9,431	3
Youth & Activity	1,373	6	8,940	3
Total	23,900	100	317,036	100

3.1.2 SCHOOL BUS SURVEYS

VRC designed and implemented two school bus surveys: one for all public schools in California; and the other for major school bus contractors in the state. In order to compile a comprehensive list of public and contractor school bus operators, VRC contacted two knowledgeable sources: Ron Kinney of the Department of Education Bus Transportation Division who provided a list of all pubic school bus operators as well as guidance on specific questionnaire design issues; and the CSBCA (California School Bus Contractors Association) which furnished a mailing list of their contractors for the contractor school bus survey.

A survey questionnaire (see Appendix B) was designed to elicit responses on school bus fleet activity and composition for calendar year 1991. The questionnaire, sent to 868 identified public school "districts" (some recipients actually represented several school districts), included many specific questions about each school bus fleet and its activities. Fleetwide activity questions included percent of VMT traveled for different activity types (home to school, deadhead, activity trip, and operator training), road types (urban surface streets, urban freeways, intercity highways, and rural roads), and day type (weekday and weekend). Also requested were fleet total VMT for 1991 and estimated relative levels of VMT for 1987, 1988, 1989, 1990, 1992 (projected) and 1993 (projected). As to fleet composition, each operator was asked to fill out an inventory form (Form A in the questionnaire) including items such as: operator status of bus (whether owned and operated by school district or contractor), body manufacturer and model, bus length, bus year of manufacture, engine manufacturer and model, fuel type, number of active and inactive buses in fleet matching the description, average lifetime miles for the described buses, average miles for the described buses in 1991, and the typical range of miles before an engine rebuild becomes necessary for the described buses.

In addition to this questionnaire, the survey packet included a cover letter from VRC, a cover letter from ARB, and instructions. After ARB approval in late October 1992, the packet was distributed to all school bus operators. Reminder postcards were mailed on November 16, 1992. Telephone followups were attempted to the 30 largest nonrespondents in late November and throughout December. The final response deadline was January 31, 1993.

Although the survey questionnaire did ask the respondent to include data for their contractor buses, it became evident that little contractor data was actually included in the responses. Therefore, VRC designed a second questionnaire specifically for the major school bus contractor companies in California. VRC used a CSBCA provided mailing list and knowledge gained from the public school survey to identify eight major school bus contractor companies in California for questionnaire distribution. The second questionnaire (also included in Appendix B) requested data on each company's entire California school bus fleet rather than local fleets as in the case of the first (school district) questionnaire. The questions pertaining to fleet activity were exactly the same as the first questionnaire. However, the fleet inventory form contained

fewer and less specific questions. It requested data on bus type (Type I vs Type II, according to the California Vehicle Code), fuel type, average annual miles for buses matching the description, and typical miles traveled before an engine rebuild becomes necessary for the described buses.

3.1.3 RESULTS OF SCHOOL BUS SURVEYS

Table 3-2 shows the number of positive responses to the two VRC-conducted school bus surveys: the public school survey and the contractor survey. For the public school survey, questionnaire packets were sent to all 868 school districts in California. Of them, 583 provided at least some kind of response. Forty-two (42) responses were too incomplete to be usable for this study, reducing the number of usable responses to 541. Some of the district responses were combined by a single transportation office which provided busing for multiple school districts.

Although the 70% response rate of the public school survey was considered high for a postal survey, the spatial distribution of the survey responses was noticeably uneven, exhibiting a few areas with little or no response. Several school districts in these low response areas informed us that their school busing was provided by a contractor. After gathering information on school bus contractors from surveyed public schools and the California Department of Education, it was found that 8 major contractors provided a great majority of the statewide contractor busing services. Of them, 7 contractors responded to the contractor survey: 5 providing both bus fleet and activity data, and 2 providing bus fleet data only.

The contractor survey response filled in many of the gaps in those low response areas from the public school survey. Of the eight major contractor companies surveyed only 1 did not respond. Among the respondents were Laidlaw Transit, Inc. and Durham Transportation, the two largest contractor companies both in terms of fleet size and fleet VMT. Table 3-3 lists the 7 responding contractors and one non-responding contractor.

Upon receiving survey responses, VRC visually scanned the data for obvious inconsistencies or omissions and re-contacted the fleet operator when necessary. Two Paradox databases linked by a VRC-assigned ID were created from the survey data: one containing response data from fleetwide questions 1 through 7 and one containing bus fleet composition data reported in Form A of the questionnaire.

Quality assurance measures were performed on the response data to check for both data input errors, survey respondent errors in calculation, and systematic errors or misunderstandings by the respondent in answering survey questions. Perceived areas of weakness in the response data include: omissions of lifetime mileage and rebuild code, inconsistent bus model and engine type responses, and diesel fuel number not always provided.

Table 3-2. SCHOOL BUS SURVEY RESPONSE RATE (Public School And Contractor)

Survey Type	No. of Questionnaires Distributed	No. of Responses	No. of Usable Responses
Public School District	868	583 (67.2%)	541 (62.4%)
Contractor	8	7 (87.5%)	7 (87.5%)

Table 3-3. MAJOR SCHOOL BUS CONTRACTORS IN CALIFORNIA

Contractor	No. Active Buses	Annual VMT
Cardinal Transportation	186	3,069,713
Durham Transportation	1533	24,064,974
Laidlaw Transit, Inc.	3095	55,179,917
Mark IV Charter Lines	702	11,847,654*
Ryder Student Transportation	132	1,748,176
Santa Barbara Transportation	189	2,396,534*
Servicar of Santa Clara	80	1,553,783
Mayflower Transportation	no response	no response
Total	5917	99,860,751

* Estimated from data of the responding contractors.

Table 3-4 shows the statewide summary results of the VRC school bus surveys as compared to the CHP school bus statistics for public schools and contractors. The public school survey identified 10,267 buses (70% of CHP's state total) and 132,722 annual bus VMT (74% of the CHP estimate). The contractor survey identified 5,917 buses as compared to 6,871 buses in the CHP estimate. The statewide coverages of the contractor survey in the number of buses and annual bus VMT are 86% and 83%, respectively. Mileage accrual rates derived from the survey results for both public school bus and contractor buses are within ±5% of the CHP's, indicating a good agreement between VRC's and CHP's survey results.

Table 3-5 summarizes the responses to some of the fleetwide questions in the public school and contractor surveys. The survey results indicate that contractor buses are more active on urban surface streets and less active on rural roads than public school buses. As to activity levels on weekdays and weekend days, both public school buses and contractor buses exhibit a minimal activity on weekend. Bus VMT fraction associated with deadhead is twice as high for public school buses as that of contractor bus. VMT fraction for pupil activity trips is about 10% of total VMT for both public school and contractor buses.

Table 3-6 shows model year distributions of public school buses and contractor buses, which were determined from the survey samples with activity data. Although the survey instructed respondents to furnish the bus fleet and activity data for calendar year 1991, many respondents appeared to have reported the data for their fiscal years ending in 1992. The model year distributions for both the public school buses and the contractor are bimodal or multimodal rather than the normally-expected unimodal. For public school buses, the highest peak occurred in 1990 and the second peak in 1978 while for contractor buses, the highest peak was in 1987 model year.

Unlike automobiles, school buses appear to be used at about the same level until their retirement from active service. Annual mileage accrual rates (MARs) of contractor buses are about the same for 21 model years, 1993 through 1973. For public school buses, 20 to 30 year old buses still accrue 8,000 to 10,000 miles per year while MARs of 1 to 10 year old buses are only about 12,000 miles to 17,000 miles per year.

As to the average age of a bus fleet, contractor buses tend to be considerable younger than public school buses. The median age of public school buses is 11 years (1981 model year) while that of contractor buses is 4 years (1988 model year), under the approximation that 1991 model year buses are 1 year old.

Table 3-4. COMPARISON OF VRC SURVEY RESULTS WITH THOSE OF CHP FOR STATEWIDE BUS POPULATION AND ANNUAL VMT.

Data Item	Public School		Contractor	
	Active Bus	Total Bus	Active Bus	Total Bus
VRC Survey				
No. of Buses	10,076	10,267	5,917	UK[c]
Annual VMT[a]	132,722	132,722	99,861	UK
MAR[b]	13,172	12,927	16,877	UK
CHP Survey				
No. of Buses	UK	14,627	UK	6,871
Annual VMT[a]	UK	178,802	UK	119,863
MAR[b]	UK	12,224	UK	17,445
% Coverage (VRC/CHP)				
No. of Buses	UK	70%	UK	86%
Annual VMT[a]	UK	74%	UK	83%
MAR[b]	UK	100%	UK	97%

[a] In 1000 vehicle miles per year
[b] Annual mileage accrual rate
[c] Unknown

Table 3-5. DISTRIBUTION OF BUS VMT OVER ROAD TYPE, WEEKDAY/WEEKEND, AND ACTIVITY TYPES FOR PUBLIC SCHOOL AND CONTRACTOR BUSES

Data Item	Public School	Contractor
% VMT by Road Type		
Urban Surface Street	51.4	75.8
Urban Freeway	16.9	11.9
Intercity Highway	5.6	6.3
Rural Road	26.1	6.1
	100.0	100.1
% VMT on WD/WE		
Weekdays	95.8	97.1
Weekend	4.2	2.9
	100.0	100.0
% VMT by Activity Type		
Home to School	68.0	74.3
Deadhead	21.3	10.5
Activity Trips	9.2	10.8
Operator Training	1.5	4.4
	100.0	100.0

Table 3-6. MODEL YEAR DISTRIBUTIONS AND ANNUAL MILEAGE ACCRUAL RATES FOR PUBLIC SCHOOL BUSES AND CONTRACTOR BUSES

Model Year	Public School[a] No. Samples[b]	Cum%	MAR (1000 mi)	Contractor[a] No. Samples	Cum%	MAR (1000 mi)
1993	0	0	0	79	1.6	15.6
1992	24	.2	12.4	229	6.1	14.6
1991	290	3.1	12.9	510	16.1	18.1
1990	893	12.0	15.2	624	28.4	18.2
1989	545	17.5	17.0	296	34.3	17.9
1988	519	22.6	16.2	446	43.1	17.4
1987	617	28.8	16.0	1311	68.9	17.0
1986	782	36.6	15.7	533	79.4	17.2
1985	412	40.7	13.4	304	85.4	16.2
1984	306	43.7	14.5	76	86.9	14.3
1983	115	44.9	12.3	18	87.2	14.9
1982	212	47.0	12.7	19	87.6	17.5
1981	252	49.5	13.4	152	90.6	15.4
1980	321	52.7	13.3	163	93.8	16.0
1979	684	59.5	12.7	73	95.3	14.4
1978	784	67.3	13.8	117	97.6	14.3
1977	500	72.0	12.5	60	98.8	13.6
1976	366	75.9	11.4	41	99.6	13.5
1975	251	78.4	11.2	7	99.7	13.2
1974	281	81.2	10.5	2	99.7	12.9
1973	266	83.9	9.7	9	99.9	12.9
1972	204	85.9	10.4	4	100.0	2.8
1971	175	87.7	10.3	0	100.0	0
1970	189	89.5	10.9	0	100.0	0
1969	174	91.3	9.3	0	100.0	0
1968	172	93.0	9.6	0	100.0	0
1967	137	94.4	9.3	0	100.0	0
1966	120	95.6	10.2	0	100.0	0
1965	81	96.4	9.6	0	100.0	0
1964	82	97.2	7.9	0	100.0	0
1963	71	97.9	8.0	0	100.0	0
1962	46	98.3	8.8	0	100.0	0
1961	48	98.8	10.0	0	100.0	0
1960	24	99.1	7.3	0	100.0	0
<1960	87	99.9	6.7	0	100.0	0
Unknown	7	100.0	7.1	0	100.0	0
Total	10,037	100.0	13.2	5,073	100.0	16.9

[a] The survey data were gathered primarily for CY1991.
[b] Only those buses with activity data.
_ The highest population fraction.
__ The second highest population fraction.

3.2 DEVELOPMENT OF ESTIMATION METHODOLOGY

CHP Motor Carrier Safety Units conduct a school bus safety and inspection survey every year for every depot or terminal in California where school buses, pupil activity buses, and/or youth buses are stored. Since the CHP school bus data are gathered regularly by a governmental agency with full enforcement authority, this database is considered to be the most reliable and complete data source for estimating school bus population and its activity level. Currently, however, original inspection records of individual buses are not available for the public. Instead, summary statistics of CHP-inspected buses for each of the 8 CHP Divisions were obtained from the CHP headquarters and used for the present study.

The CHP data provide only bus counts and annual VMT by Type I(large)/Type II(small) buses at the CHP Division level. To supplement the CHP data, VRC conducted two school bus surveys: public school survey and contractor survey. These surveys yielded bus fleet characterization data such as vehicle age distribution, fuel type mix, and bus length information. Using these supplemental data gathered by the two surveys and a few other data sources, a methodology of estimating school bus population and activity levels from the current and future CHP data was developed. This estimation methodology is shown in Figure 3-2 in a logic flow diagram.

The methodology shown in Figure 3-2 actually involves the following five data transformation steps:

(1) Develop a relationship between bus length and GVW to assign buses with length information to correct weight classes;

(2) For public school buses, first convert bus counts with length information to those of weight classes using the relationship and then compute a weight class mix of buses in each CHP Division and fuel mix for each weight class at the CHP Division level.

(3) For non-public school buses, first develop a method of splitting Type I and Type II buses into three ARB weight classes and then compute a fuel mix of buses for each weight class at the state level;

(4) Using results of Steps (2) and (3), transform the CHP bus count and VMT data into those of the three weight classes and three fuel types; and

(5) Finally, disaggregate the bus count and VMT estimates at the Division level into county-specific estimates of school bus population and VMT by weight class and fuel type using an allocation scheme based on student enrollments (see Appendix C for enrollment data) for public and private schools in each county.

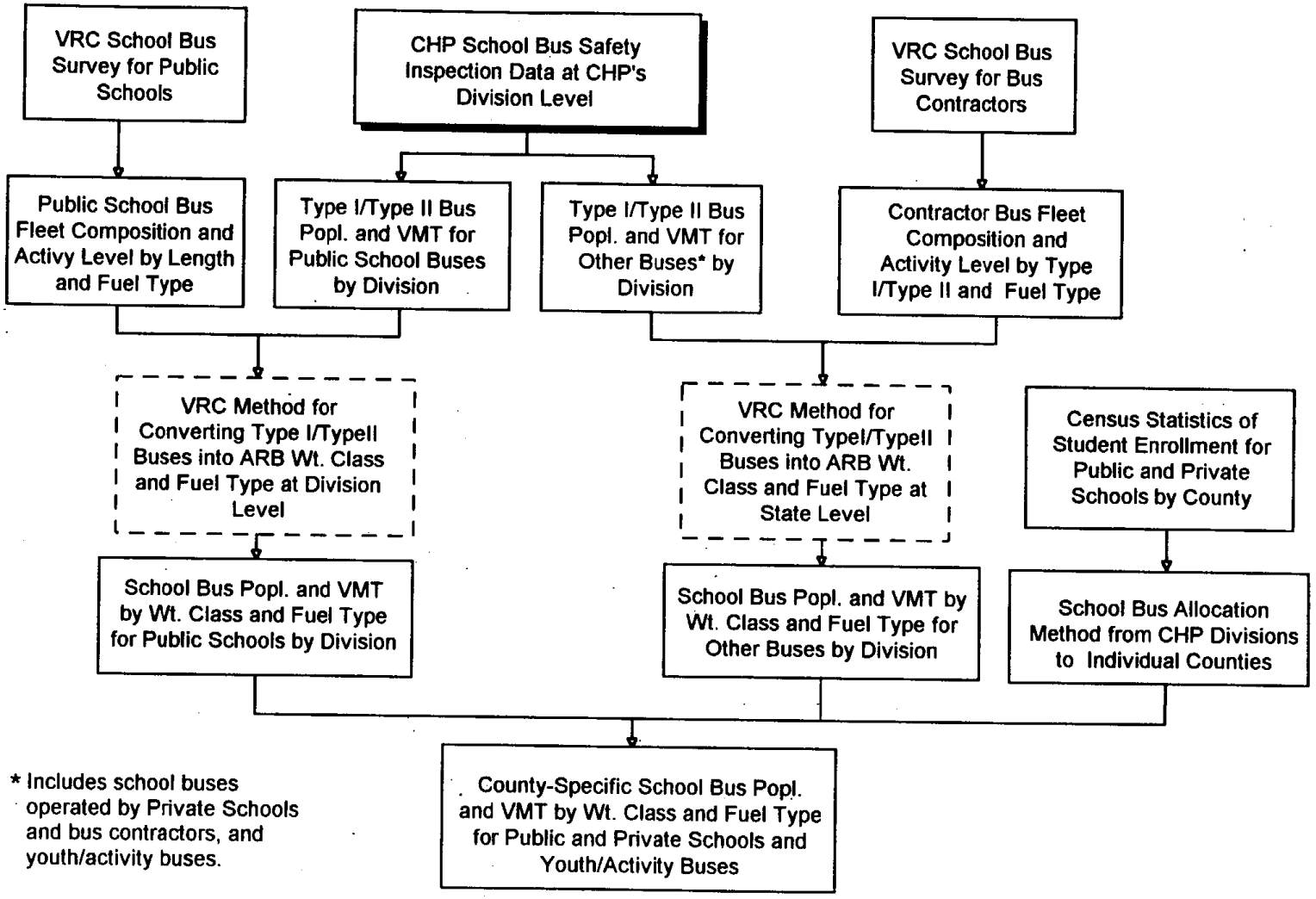

Figure 3-2. Methodology Used for Developing County-Specific Estimates of School Bus Population and VMT by Weight Class and Fuel Type

In Step 1, VRC obtained bus specification data of total length and GVWR for a few common school bus models from the California Department of Education and school bus dealers. The Department of Education's school bus specification states that every school bus must weigh at least 8500 pounds GVW. Therefore, all school buses were judged to be HDVs. Table 3-7 lists bus length and GVWR for six common school bus models. From this table, it was estimated that dividing bus lengths between LHDV and MHDV and between MHDV and HHDV would be 23 feet and 33 feet respectively. Figure 3-3 shows the regions of LHDV, MHDV, and HHDV over the range of actual bus lengths for 9,864 public school buses surveyed by VRC. It should be noted that a weight class mix of school buses would be affected very little by slightly shifting the dividing lengths to either direction.

In Step 2, all surveyed public school buses with length information were assigned the corresponding weight classes using the relationship shown in Figure 3-3. By stratifying the buses into each of the CHP's 8 Divisions, both a weight class mix for the bus population and that for bus VMT were computed for each weight class of buses in each Division. Table 3-8a lists all fractional values of buses in each weight class and those powered by each fuel type for each CHP Division, separately.

In Step 3, all buses with length information in the VRC contractor bus survey sample were first assigned to the corresponding wight classes using the length-GVWR relationship of Figure 3-3. Statistical analyses of the VRC contractor bus survey data and the CHP contractor bus data yielded weight class distributions and Type I/Type II bus distributions over bus counts and VMT as shown in Figure 3-4. From this figure, it is evident that Type II buses are all LHDVs. Using the statistics shown in the figure, CHP Type I bus data for non-public school buses were split into three HDV subclasses as follows:

	No. of Buses	Annual VMT
LHDV fraction	.06	.07
MHDV fraction	.16	.16
HHDV fraction	.78	.77
Total	1.00	1.00

A fuel mix of non-public buses in each weight class was determined from actual proportions of gasoline and diesel buses* found in the survey sample. Table 3-8b lists all fractional values used to allocate Type I and Type II buses of contractors to correct weight class and fuel type categories. The same fractional values were used to allocate private school bus, youth bus, and pupil activity bus as well.

* No buses powered by other fuels were found in the VRC contractor bus survey sample.

Table 3-7. BUS SPECIFICATION DATA FOR A FEW COMMON SCHOOL BUS MODELS

Bus Model	Model Years	Length(ft)	GVWR(lbs)	Weight Class
All American	'88-'93	37-40	34,000	HHDV
TC2000	'88-'93	27-32	30,000	MHDV
Minibird	'84-'93	24	14,500	MHDV
Microbird	'80-'93	21	10,000	LHDV
Cadet	'84-'93	24	14,500	MHDV
Mini	'84-'93	21	10,000	LHDV

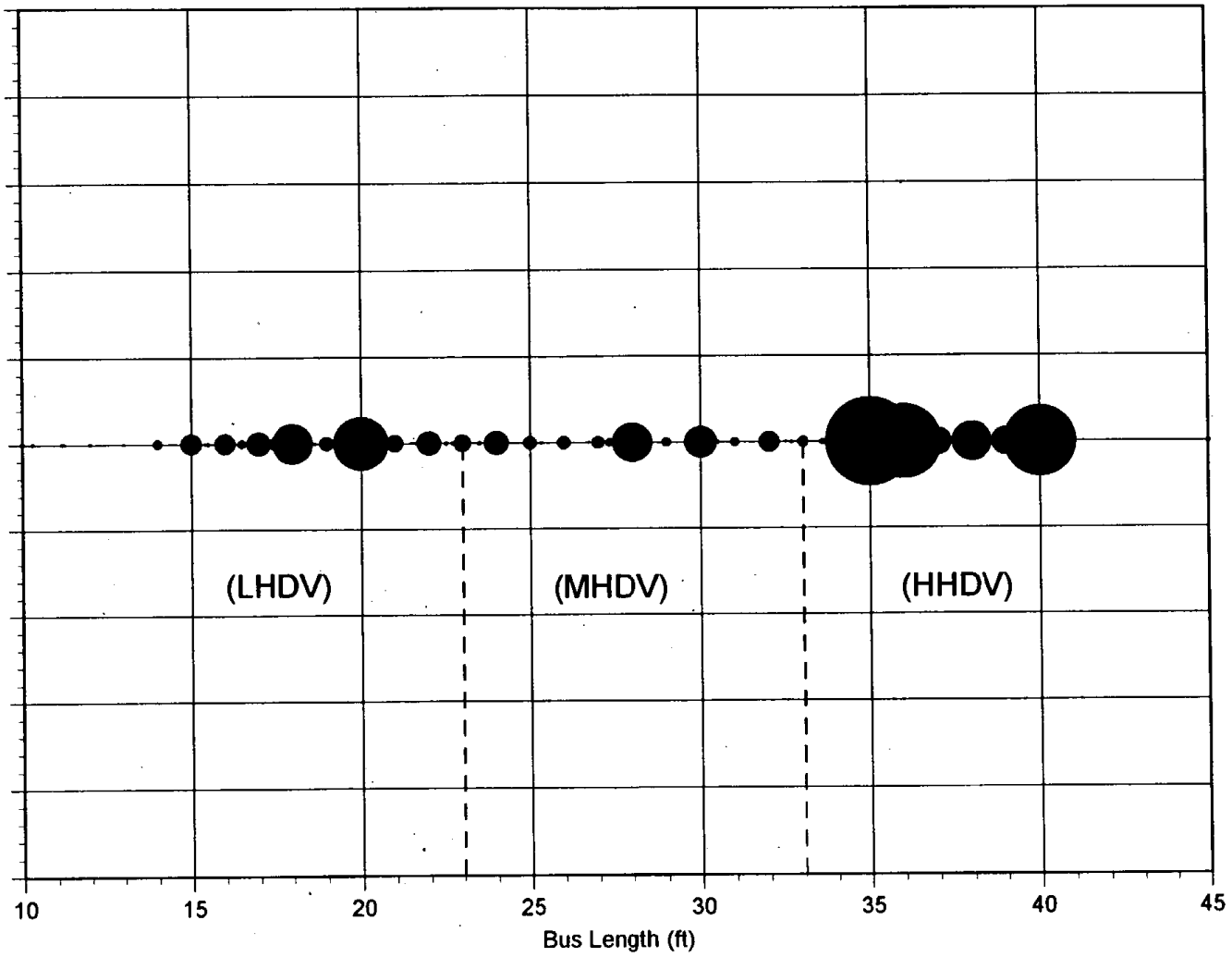

Figure 3-3. Recommended Ranges of Bus Length for LHDV, MHDV, and HHDV over the Actual Distribution of School Bus Lengths (n=9864: the size of each bubble is proportional to the number of data points.)

Table 3-8a. FRACTIONAL VALUES USED IN ALLOCATING CHP PUBLIC SCHOOL BUS POPULATION AND VMT TO EACH WEIGHT CLASS AND FUEL TYPE

CHP Division[1]	Fuel Type[2]	LHDV No.	LHDV VMT	MHDV No.	MHDV VMT	HHDV No.	HHDV VMT
1	D	.065	.083	.098	.119	.565	.583
1	G	.119	.112	.056	.037	.087	.057
1	O	.000	.000	.000	.000	.010	.008
2	D	.071	.091	.030	.028	.578	.587
2	G	.227	.236	.029	.024	.063	.034
2	O	.001	.000	.001	.000	.000	.000
3	D	.159	.205	.064	.068	.530	.530
3	G	.167	.154	.022	.017	.058	.026
4	D	.106	.142	.046	.075	.703	.682
4	G	.050	.041	.027	.014	.054	.030
4	O	.000	.000	.000	.000	.014	.014
5	D	.049	.052	.158	.160	.529	.559
5	G	.202	.190	.035	.029	.022	.010
5	O	.000	.000	.000	.000	.005	.000
6	D	.099	.114	.153	.196	.521	.502
6	G	.135	.127	.019	.015	.052	.030
6	O	.002	.002	.000	.000	.018	.014
7	D	.161	.290	.052	.040	.569	.507
7	G	.121	.111	.046	.022	.045	.026
7	O	.000	.000	.000	.000	.005	.004
8	D	.039	.044	.100	.112	.652	.688
8	G	.075	.065	.026	.019	.071	.034
8	O	.000	.000	.000	.000	.037	.038

[1] Fractions sum to 1 for each CHP Division. Includes both Type I & II buses.
[2] D - diesel, G - gasoline, O - other

VRC Data
(N =)

	HHDV	MHDV	LHDV
% N =	64	13	23
% VMT =	62	13	25

CHP Data
(N =)

	Type I	Type II
% N =	82	18
% VMT =	81	19

Type II Buses are all LHDVs
Type I Buses should be split as follows:

	HHDV	MHDV	LHDV
%N	$\frac{64}{.82} = 78$	$\frac{13}{.82} = 16$	$\frac{23-18}{.82} = 6$
%VMT	$\frac{62}{.81} = 77$	$\frac{13}{.81} = 16$	$\frac{25-19}{.81} = 7$

Figure 3-4. Method of Splitting CHP Type I Bus Data into Three HDV Subclasses.

Table 3-8b. FRACTIONAL VALUES USED IN ALLOCATING CHP CONTRACTOR, PRIVATE SCHOOL, YOUTH, AND ACTIVITY BUS POPULATION AND VMT TO EACH WEIGHT CLASS AND FUEL TYPE

CHP Bus Type[1]	Fuel Type[2]	LHDV		MHDV		HHDV	
		No.	VMT	No.	VMT	No.	VMT
1	D	.059	.071	.152	.154	.749	.735
1	G	.002	.003	.006	.006	.031	.031
2	D	.820	.840	.000	.000	.000	.000
2	G	.180	.160	.000	.000	.000	.000

[1] Fractions sum to 1 for each CHP bus type.
[2] D - diesel, G - gasoline

Step 4 was accomplished entirely in a computer data processing operation by applying the weight class mix and fuel mix table developed in Steps 2 and 3 to the original data records. Step 5 involved the use of student enrollment statistics as apportioning factors for individual counties. Specifically, the 1990 Census summary of student (elementary to high school level) enrollments in public and private schools was used.

3.3 ESTIMATE OF SCHOOL BUS POPULATION AND VMT

The CHP school bus safety inspection data which are annually updated were considered to represent the school bus universe in California. The CHP school bus data have five components:

- School buses operated by public schools
- School buses operated by contractors
- School buses operated by private school
- Youth buses
- Pupil activity buses

As Table 3-1 shows, the public school buses accounted for the largest proportion of statewide buses, followed by the contractor buses. The last three components (i.e., private school bus, youth bus and activity bus) account for a much smaller proportion than the first two components. Therefore, an effort was made to allocate CHP estimates of public school bus population and VMT to weight class, fuel type, and individual county as accurately as possible, using the detailed fleet data gathered in the VRC public school bus survey that covered roughly 70% of these buses and their VMT.

A less rigorous allocation method was used for contractor buses. Allocation factors for weight classes and fuel types were developed at the state level instead of the CHP Division level as for public school buses, based on the fleet data gathered in the VRC contractor bus survey. The same allocation method for contractor buses was applied to private school buses, youth buses, and pupil activity buses.

The estimation methodology depicted in Figure 3-2 was applied to the CHP school bus data to yield various estimates of school bus population and VMT for ARB weight classes and fuel types at state and county levels. Table 3-9 shows statewide school bus population and annual VMT by weight class and fuel type. In this table, the term of "school bus" was used in a narrow sense: the school bus consists of regular (yellow) school buses operated by public schools, contractors, and private schools; and it excludes youth buses and school pupil activity buses. Statewide population and VMT of youth and activity buses are given in Table 3-10.

Table 3-9. STATEWIDE ESTIMATE OF SCHOOL BUS POPULATION AND ANNUAL VMT BY WEIGHT CLASS AND FUEL TYPE (Excluding Youth & Activity Buses)

Weight Class	Diesel		Gasoline		Other		Total	
	Number	VMT*	Number	VMT*	Number	VMT*	Number	VMT*
LHDV	4567	79818	2740	35153	8	71	7315	115042
MHDV	2065	29891	467	4236	2	1	2534	34128
HHDV	11639	150496	892	6947	147	1483	12678	158926
Total	18271	260205	4099	46336	157	1555	22527	308096

* In 1000 vehicle miles of travel

Table 3-10. STATEWIDE ESTIMATE OF YOUTH AND PUPIL ACTIVITY BUS POPULATION AND ANNUAL VMT BY WEIGHT CLASS AND FUEL TYPE

Weight Class	Diesel		Gasoline		Other		Total	
	Number	VMT*	Number	VMT*	Number	VMT*	Number	VMT*
LHDV	165	1305	20	163	0	0	185	1468
MHDV	197	1239	8	52	0	0	205	1291
HHDV	942	5934	40	247	0	0	982	6181
Total	1304	8478	68	462	0	0	1372	8940

* In 1000 vehicle miles of travel

Table 3-9 indicates that diesel buses account for a great majority of both school bus population (81%) and annual VMT (84%). Gasoline buses take the remaining population and VMT, leaving practically none for other fuel buses. Among the three HDV subclasses, HHDVs weighing over 33,000 GVW account for over a half of the state total bus population (56%) and VMT (51%). LHDVs account for about a third of the population (33%) and VMT (37%). MHDVs account for 11 percent of both the population and VMT. Table 3-10 shows that practically all of youth and pupil activity buses consist of diesel buses.

Table 3-11 shows annual mileage accrual rates (MARs) of school buses for three HDV subclasses and three fuel types. It indicates that LHDVs, on average, are driven more than 25% more than other fuel buses. Diesel-powered LHDV buses are driven the most among all nine combinations of buses by weight class and fuel.

Table 3-12 lists MARs for school buses by three operator types (public school, contractor, and private school) and for youth and pupil activity buses. Contractor buses are driven about 50% more than public school buses and 2 times as many miles as the last three category buses: private schools, youth bus, and pupil activity bus.

Table 3-13 provides the numbers of school buses (including youth and activity buses) for three HDV subclasses for all 58 counties in California. The state total of school buses is 23,910, more than two times as many as transit buses. Los Angeles county has the largest fleet, accounting 26% of the state total. Orange and San Diego counties are the distant 2nd and 3rd places with each having about 1700 buses or 7% of the state total.

Table 3-14 provides annual bus VMT for all 58 counties in the state. The statewide bus VMT is 318 million vehicle-miles per year. This school bus VMT is only about one tenth of a percent of total VMT, which is 259 billion vehicle miles in 1990.

Table 3-11. ANNUAL MILEAGE ACCRUAL RATES OF SCHOOL BUSES BY WEIGHT CLASS AND FUEL TYPE (Excluding Youth and Activity buses)

Weight Class	Diesel	Gasoline	Other	Total
LHDV	17,359	13,163	8,875	15,814
MHDV	14,492	9,073	500	13,482
HHDV	12,945	7,796	10,088	12,549
Total	14,224	11,505	9,904	12,715

Table 3-12. ANNUAL MILEAGE ACCRUAL RATES OF SCHOOL BUSES BY OPERATOR AND BUS TYPE

Operator/Bus Type	MAR (mi/y)
Public School	12,945
Contractor	19,004
Private School	9,189
Youth Bus	9,647
Pupil Activity Bus	9,362

Table 3-13. ESTIMATED NUMBER OF SCHOOL BUSES AND YOUTH & ACTIVITY BUSES BY WEIGHT CLASS AT THE COUNTY LEVEL

County	LHDV	MHDV	HHDV	Total
ALAMEDA	340	63	375	779
ALPINE	0	0	1	1
AMADOR	10	2	19	31
BUTTE	61	12	117	190
CALAVERAS	12	3	23	38
COLUSA	6	5	22	33
CONTRA COSTA	228	42	252	523
DEL NORTE	7	6	24	37
EL DORADO	49	10	95	154
FRESNO	193	54	501	748
GLENN	9	7	30	46
HUMBOLDT	35	28	121	184
IMPERIAL	36	18	68	122
INYO	4	2	9	15
KERN	151	46	385	582
KINGS	29	8	75	112
LAKE	14	11	49	75
LASSEN	8	7	29	44
LOS ANGELES	1915	923	3415	6253
MADERA	26	7	68	102
MARIN	48	9	52	109
MARIPOSA	3	1	8	11
MENDOCINO	26	21	90	136
MERCED	57	16	146	219
MODOC	3	3	11	17
MONO	3	1	6	10
MONTEREY	116	35	202	353
NAPA	30	6	33	69
NEVADA	28	6	54	88
ORANGE	518	251	943	1712
PLACER	64	14	123	200
PLUMAS	6	5	22	32
RIVERSIDE	283	132	580	995
SACRAMENTO	380	77	727	1185
SAN BENITO	14	4	25	43
SAN BERNARDINO	372	159	855	1386
SAN DIEGO	522	256	959	1737
SAN FRANCISCO	143	26	154	323
SAN JOAQUIN	131	37	337	505
SAN LUIS OBISPO	58	17	100	175
SAN MATEO	160	30	174	363
SANTA BARBARA	101	30	176	308
SANTA CLARA	411	76	454	941
SANTA CRUZ	65	19	113	198
SHASTA	47	36	157	240
SIERRA	1	0	2	3
SISKIYOU	13	11	48	73
SOLANO	110	20	122	252
SONOMA	107	20	118	245
STANISLAUS	102	29	263	394
SUTTER	28	6	53	87
TEHAMA	16	13	57	86
TRINITY	4	3	15	23
TULARE	97	27	253	377
TOULUMNE	11	3	27	41
VENTURA	220	66	383	669
YOLO	47	9	89	145
YUBA	26	5	50	82
TOTAL:	7509	2731	13660	23900

Table 3-14. ESTIMATED ANNUAL VMT FOR SCHOOL BUSES AND YOUTH & ACTIVITY BUSES BY WEIGHT CLASS AT THE COUNTY LEVEL

(All values in 1000 vehicle miles of travel)

County	LHDV	MHDV	HHDV	Total
ALAMEDA	5161	636	3658	9455
ALPINE	8	1	10	19
AMADOR	186	22	234	442
BUTTE	1140	136	1430	2706
CALAVERAS	226	27	284	537
COLUSA	77	62	259	397
CONTRA COSTA	3461	427	2459	6347
DEL NORTE	86	68	286	441
EL DORADO	925	110	1165	2200
FRESNO	3382	687	5306	9375
GLENN	107	85	357	548
HUMBOLDT	425	339	1421	2184
IMPERIAL	525	285	875	1686
INYO	54	21	110	184
KERN	2599	577	4151	7286
KINGS	505	103	790	1398
LAKE	172	138	578	888
LASSEN	101	81	340	522
LOS ANGELES	28211	12647	48449	89308
MADERA	461	94	723	1278
MARIN	728	90	508	1325
MARIPOSA	52	10	81	143
MENDOCINO	315	250	1048	1613
MERCED	990	202	1550	2742
MODOC	38	31	130	200
MONO	62	7	78	147
MONTEREY	2059	285	2064	4408
NAPA	454	56	322	832
NEVADA	531	64	667	1262
ORANGE	7420	3898	12157	23475
PLACER	1205	144	1504	2854
PLUMAS	74	60	252	387
RIVERSIDE	4011	1881	7252	13143
SACRAMENTO	7133	855	8877	16865
SAN BENITO	252	35	253	540
SAN BERNARDINO	5139	1957	10302	17398
SAN DIEGO	7516	3991	12382	23889
SAN FRANCISCO	2166	266	1502	3934
SAN JOAQUIN	2282	468	3562	6311
SAN LUIS OBISPO	1017	143	1023	2182
SAN MATEO	2422	298	1700	4421
SANTA BARBARA	1792	252	1803	3846
SANTA CLARA	6225	767	4424	11416
SANTA CRUZ	1151	161	1157	2469
SHASTA	556	439	1840	2834
SIERRA	20	2	25	47
SISKIYOU	167	135	567	869
SOLANO	1660	205	1186	3051
SONOMA	1616	199	1153	2968
STANISLAUS	1779	363	2783	4925
SUTTER	521	62	653	1236
TEHAMA	197	159	665	1021
TRINITY	52	42	176	270
TULARE	1704	346	2674	4724
TOULUMNE	185	38	288	510
VENTURA	3886	548	3913	8347
YOLO	873	105	1088	2066
YUBA	489	58	618	1165
TOTAL:	116510	35419	165107	317036

4.0 STUDY OF BUS DRIVING PATTERNS

Under the current methodology for estimating emissions from on-road vehicles, buses are assigned the same VMT-by-speed distribution as all other vehicles. It is well known, however, that buses have a distinct driving pattern that includes frequent stopping and extended idling for passenger loading and unloading. The objective of the chase car survey was to develop new estimates of VMT by 5 mph speed increments specifically for buses operating in three area types based on urbanization. This was accomplished using instrumented "chase cars" that followed buses selected from routes in each area type. The chase cars were automobiles equipped with a data logging system capable of digitally recording trip start time, end time, travel time spent in each 5 mph speed increment, time spent in each of five acceleration ranges, and the frequency and time spent idling for each of three ranges of idling duration.

4.1 SURVEY DESIGN

Since the chase car survey was planned to be conducted only in the South Coast Air Basin (SCAB), VRC developed a sampling methodology to ensure that the survey results would be applicable to other parts of the state. VRC assigned chase car survey routes to the following three broad area types:

Urbanized -- Cities and their fringe areas having a minimum of 50,000 persons and a density of at least 1000 persons per square mile.

Small Urban -- Places of a minimum of 2,500 persons and a maximum of 50,000 persons.

Rural -- Places of less than 2,500 persons and outside incorporated places.

This area categorization is readily available from census data summary throughout the state. According to the 1980 census, "Rural" accounts for only 8% of the statewide population while "Urbanized" and "Small Urban" account respectively for 55% and 37%. Using this population distribution as a reference, the sample allocation of chase car survey routes to each area type was made in the following manner (see Table 4-1).

For transit buses, 60% of the total number of survey routes were assigned to "urbanized" and 40% to "small urban". Since except for inter-city buses, no transit buses were expected to be in rural areas, none of the transit bus survey routes were assigned to "rural".

Table 4-1. ALLOCATION OF CHASE CAR STUDY ROUTES TO AREA TYPES AND TIME PERIODS

Type Bus/Time Period	Area Type			Total
	Urbanized	Small Urban	Rural	
Transit Bus				
WD - Peak Hour*	30	20	none	50
WD - Off Peak	30	20	none	50
Saturday	12	16**	none	20
Sunday/Holiday	12	**	none	20
Subtotal	84	56	none	140
School Bus				
WD - Morning	14	14	7	35
WD - Afternoon	14	14	7	35
Subtotal	28	28	14	70
Grand Total	112	84	14	210

* 0600-0900 and 1500-1800 in local prevailing time

** Since there are very few bus services on Sundays in small urban areas, these chase car routes were surveyed on weekend days.

For school buses, 40% of the total number of survey routes were assigned each to "urbanized" and to "small urban" while 20% of the routes were assigned to "rural". The reason for the greater-than-proportional allocation to "rural" is that pupils in rural areas are more likely to be school-bused than those in urban areas.

The driving patterns of transit buses were determined for four time periods: weekday peak traffic hours (6-9 A.M. and 3-6 P.M. in local prevailing time), weekday off-peak hours, Saturdays, and Sundays/Holidays. For school buses, the driving patterns were determined only for weekday morning hours and weekday afternoon hours. Because of the four distinct time periods for transit buses versus the two time periods for school buses, the number of survey routes for transit buses was twice as many as for school buses.

Actual route selections were made in the following manner. A SCAG-prepared map (Figure 4-1) shows areas of "highly urbanized", "urbanizing" and "mountain/desert" over the six county region: Los Angeles, Orange, Riverside, San Bernardino counties plus two non-SCAB counties of Ventura and Imperial. Since SCAG's definitions of the three area types are quite similar to the census' categorization of "urbanized", "small urban", and "rural", VRC approximated the spatial distribution of the three area types following the SCAG map. Using the SCAG base map, VRC then determined a predominant area type for each of the transit bus routes which VRC has assembled. Both primary survey routes and some alternate routes were selected on a random basis for each area type and each time period according to the sample allocation plan in Table 4-1. For school buses, the acquisition of exact school bus routes was rather difficult. Since a majority of school bus routes are clustered around each serving school or a group of schools, survey routes were specified only by survey "target" school. The number and location of the target schools were selected randomly for each of the three area types according to the sample allocation plan in Table 4-1.

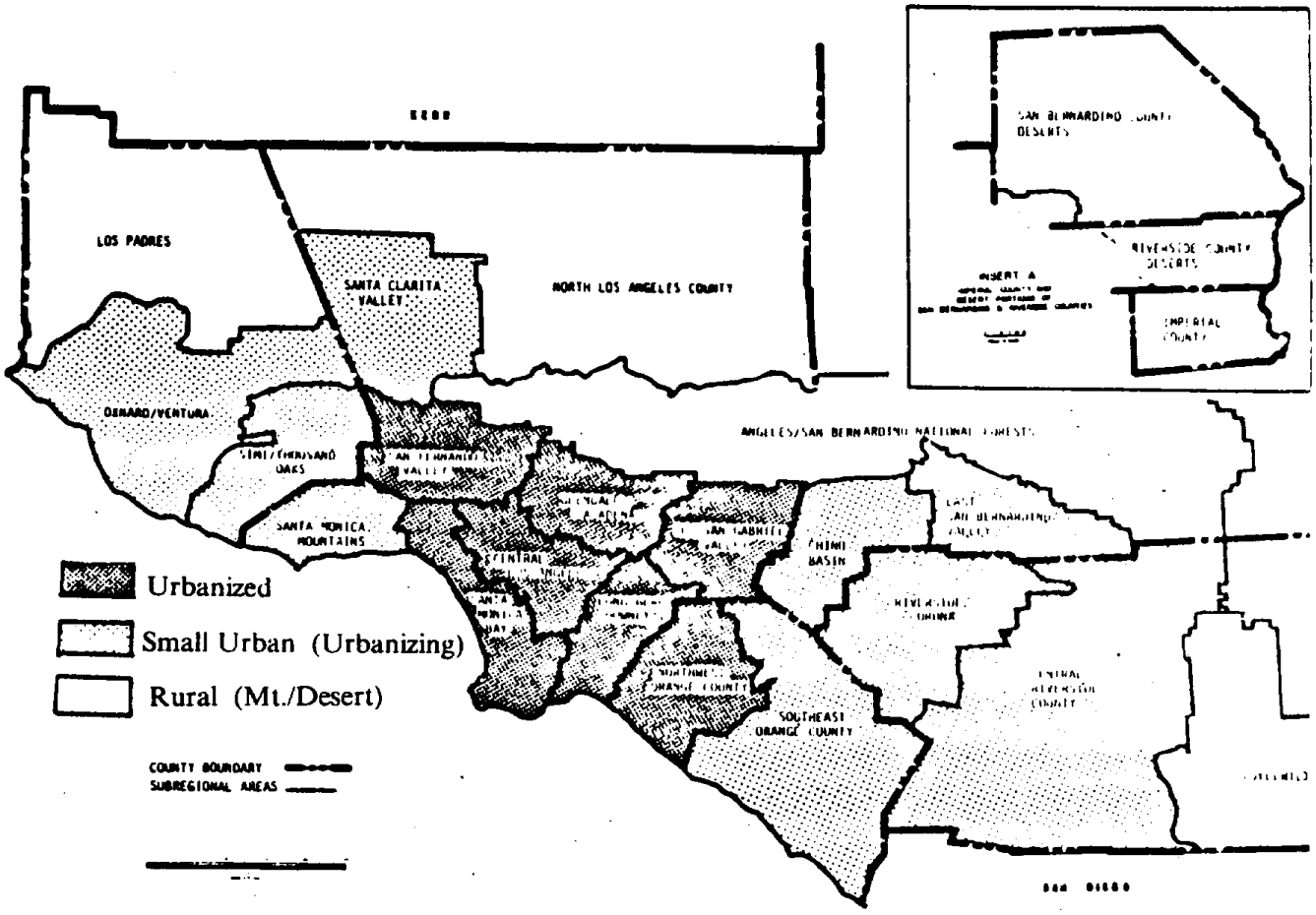

Figure 4-1. SCAG Regional Map Showing Subregions by Three Area Types

4.1.1 SELECTION METHODOLOGY FOR TRANSIT BUS SURVEY ROUTES

The same set of transit bus routes were surveyed twice on weekdays, once during the peak hour (6-9 A.M. and 3-6 P.M.) period and once during the off peak hour period. A subset of routes was selected from the weekday's set and surveyed again on Saturdays and Sundays/Holidays. Survey route selections were made separately for urbanized areas and small urban areas in the following steps:

(1) All scheduled transit bus routes in the SCAG region were obtained from operators and sorted them into two area types by designating each route either as in predominantly "urbanized" areas or in predominantly "small urban" areas. When a route was in rural areas or consisted of a near-even mixture of both "urbanized" and "small urban" areas, the route was excluded from any further considerations.

(2) A sequential number was assigned to the transit routes compiled in Step 1, separately for urbanized areas and for small urban areas.

(3) Referring to Table 4-1, the target numbers of routes to be surveyed for urbanized areas and for small urban areas during the WD-peak hour period were determined.

(4) A survey route was selected from the routes listed for each area type without replacement until the number of selected routes reached 1.5 times as many as the target number of routes assigned to the area type.

(5) The same routes as those of the WD-peak period were used for the WD-off peak period. A subset of the survey routes selected for the weekday periods was used for the two weekend periods, namely, Saturday and Sunday/Holiday.

Initial candidate survey routes were selected according to the above selection steps. The number of candidate routes was selected for urbanized areas and small urban areas about 1.5 times as many as the target number of routes allocated to each area type. Individual candidate routes were then evaluated as to the bus schedule for each of the three (for Small Urban) or four (for Urbanized) time periods and the plausibility of the service routes for a chase car study. An official request-for-cooperation letter, signed by the ARB contract manager, was sent to the fleet manager of each transit agency whose service routes were selected for the chase car study.

Table 4-2 shows the number of total service routes in each transit district and the numbers of initial candidate routes and final study routes by transit district for "urbanized" areas. There are 301 bus service routes operated by 10 transit districts over the urbanized areas. Of them, 49

Table 4-2. NUMBERS OF BUS SERVICE ROUTES, INITIAL CANDIDATE ROUTES, AND FINAL STUDY ROUTES BY TRANSIT AGENCY IN URBANIZED AREAS

Transit District	County	Total Serv. Routes	Candidate Routes	Study Routes
Southern Cal. Rapid Transit	LA[a]	178	33	17
Gardena Transit	LA	4	1	1
Orange County Transit	OR[b]	51	5	4
Long Beach Transit	LA	21	5	3
Torrance Transit	LA	9	0	0
Commerce Transit	LA	7	1	1
Norwalk Transit	LA	3	0	0
Santa Monica Transit	LA	11	2	2
Culver Cuty Transit	LA	6	1	1
Montebello Transit	LA	11	1	1
All Districts		301	49	30

[a] Los Angeles County, [b] Orange County

service routes were selected for candidate routes on a random basis and 30 routes were actually used for the chase car study on bus driving patterns in urbanized areas. Among the 10 transit districts, the Southern California Rapid Transit District (SCRTD) is by far the largest district, providing about 60 percent of total bus service routes over the urbanized areas of the study region. Table 4-3 lists individual service routes and time periods during which actual chases of the buses were conducted. In total, 30 service routes were studied by chasing the buses for about 30 minutes each during the weekday peak-traffic period (6-9 AM and 3-6 PM) and the weekday off-peak traffic period. For Saturdays and Sundays, 12 service routes each were studied by following the buses for about 30 minutes with a datalogger-equipped vehicle.

"Small Urban" is defined in the U.S. Census report as places of a minimum of 2,500 persons and a maximum of 50,0000 persons. Although some cities (e.g., Ventura and Riverside) in the SCAG subregions designated as "Urbanizing" have more than 50,000 persons, the majority of places in the subregional areas meet the definition of "small urban". Therefore, VRC selected chase car study routes from transit bus routes in the "urbanizing" portions of the SCAG region (see Fig. 4-1). As shown in Table 4-4, there are nine transit districts operating, in total, 88 service routes over the study region. VRC selected, on a random basis, 30 candidate routes for small urban areas from these service routes. Of them, 20 routes were used for actual chase car study.

The largest transit district for small urban portions of the SCAG region is Omnitrans (OMNI) serving 27 scheduled service routes in San Bernardino County, closely followed by Riverside Transit Agency (RTA) serving 23 routes in Riverside County. The South Coast Area Transit (SCAT) serving 17 routes in Ventura County is the third largest. Santa Clarita transit in Los Angeles County and Laguna Beach Transit in Orange County are considerably smaller than the three largest transit districts.

Table 4-5 lists all 20 service routes used for the chase car study on bus driving patterns in small urban areas. The same service route was used for bus chases twice; once during the weekday peak traffic hours (6-9 AM and 3-6 PM) and once during the weekday off-peak traffic period.

A subset of 8 routes was also used for bus chases on weekend days. Since transit bus services on Sundays were found to be either non-existent or very infrequent, most of these service routes were used for bus chases twice on Saturdays instead of one chase on Saturday and the other on Sunday.

Table 4-3. THIRTY TRANSIT BUS SERVICE ROUTES AND FOUR TIME PERIODS COVERED BY CHASE CAR STUDY FOR **URBANIZED** AREAS

Transit District	Service Route No.	County	Study Period			
			WD-P	WD-OP	Sat.	Sun.
SCRTD	1	LA	✓	✓	✓	✓
SCRTD	27	LA	✓	✓		
SCRTD	55	LA	✓	✓	✓	✓
SCRTD	84	LA	✓	✓		
SCRTD	102	LA	✓	✓	✓	✓
SCRTD	105	LA	✓	✓		
SCRTD	107	LA	✓	✓		
SCRTD	166	LA	✓	✓	✓	✓
SCRTD	181	LA	✓	✓		
SCRTD	250	LA	✓	✓		
SCRTD	270	LA	✓	✓		
SCRTD	331	LA	✓	✓	✓	✓
SCRTD	427	LA	✓	✓		
SCRTD	429	LA	✓	✓		
SCRTD	434	LA	✓	✓	✓	✓
SCRTD	439	LA	✓	✓	✓	✓
SCRTD	487	LA	✓	✓		
Gardena	3	LA	✓	✓		
OCTD	57	OR	✓	✓	✓	✓
OCTD	69	OR	✓	✓	✓	✓
OCTD	75	OR	✓	✓		
OCTD	99	OR	✓	✓		
Long Beach	15	LA	✓	✓	✓	✓
Long Beach	61	LA	✓	✓		
Long Beach	161	LA	✓	✓	✓	✓
Commerce	G	LA	✓	✓		
Santa Monica	8	LA	✓	✓	✓	✓
Santa Monica	11	LA	✓	✓		
Culver City	3	LA	✓	✓		
Montebello	10	LA	✓	✓		
All Districts			30	30	12	12

[a] Los Angeles County, [b] Orange County

Table 4-4. NUMBERS OF BUS SERVICE ROUTES, INITIAL CANDIDATE ROUTES, AND FINAL STUDY ROUTES BY TRANSIT AGENCY IN SMALL URBAN AREAS

Transit District	County	Total Serv. Routes	Candidate Routes	Study Routes
Omnitrans (OMNI)[d]	SB	27	9	5
Riverside (RTA)[c]	RV	23	7	5
Santa Clarita[a]	LA	8	3	2
Laguna Beach[b]	OR	3	1	1
Simi Valley[e]	VN	4	2	2
Thousand Oaks	VN	3	1	0
Camarillo	VN	2	1	0
Interconnect	VN	1	0	0
South Coast Area (SCAT)	VN	17	6	0
All Districts		88	30	20

[a,b] See Table 4-3, [c] Riverside County, [d] San Bernardino County, [e] Ventura County

Table 4-5. TRANSIT BUS SERVICE ROUTES AND TIME PERIODS COVERED BY CHASE CAR STUDY FOR **SMALL URBAN** AREAS

Transit District	Service Route No.	County	Study Period		
			WD-P	WD-OP	WE
OMNI	9	SB[d]	✓	✓	
OMNI	20	SB	✓	✓	
OMNI	32	SB	✓	✓	
OMNI	60	SB	✓	✓	✓✓
OMNI	64	SB	✓	✓	✓✓
Riverside	10	RV[c]	✓	✓	✓✓
Riverside	22	RV	✓	✓	
Riverside	23	RV	✓	✓	
Riverside	25	RV	✓	✓	
Riverside	31	RV	✓	✓	✓✓
Santa Clarita	10	LA[a]	✓	✓	✓✓
Santa Clarita	35	LA	✓	✓	
Laguna Beach	R	OR[b]	✓	✓	
Simi Valley	A	VN[e]	✓	✓	
Simi Valley	D	VN	✓	✓	
SCAT	5	VN	✓	✓	✓✓
SCAT	6C	VN	✓	✓	✓✓
SCAT	12	VN	✓	✓	✓✓
SCAT	15	VN	✓	✓	
SCAT	17	VN	✓	✓	
All Districts			20	20	16

[a, b, c, d, e] See Table 4-4.

4.1.2 SELECTION METHODOLOGY FOR SCHOOL BUS SURVEY ROUTES

School bus survey routes were selected for three area types: urbanized (U), small urban (S), and rural (R). In determining each survey route, a target school was selected first, and then, an actual survey route was selected from all school bus routes served by the school. School-bus survey routes were selected as follows:

(1) Using the Thomas Guides* of SCAG member counties and the SCAG's area-type map, a set of Thomas Guide pages containing at least one school per page for each area type was prepared, and a serial number was assigned to each page.

(2) A series of 5-digit random numbers was generated: the first three digits indicating the serialized page number, the fourth digit indicating the row of the Thomas Guide page, and the last digit indicating the column of the page.

(3) The rectangular coordinate specified by the 4-th and 5-th digits of the random number was identified for each selected page.

(4) The school nearest to the coordinate in the page was identified and the type, name, and address of the school was recorded for a later inquiry about the school bus routes served by the school.

(5) Steps 3 and 4 were repeated until the number of selected schools reached 1.5 times as many as the target number of survey routes assigned to each area type.

(6) A list of schools selected for each area type was developed by recording the Thomas Guide page, the school type (elementary, junior high, and high schools), the names of the street and cross street, the local city or community name, and the likely school district to which the school belongs.

(7) All relevant school districts were contact to obtain the bus route information for each selected school such as the number of school bus routes, the route description and time schedule, location(s) of school bus depot, and the name and telephone number of the fleet manager.

(8) One route per each selected school was selected for the chase car survey, and the route information data for all candidate survey routes for school buses were prepared.

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* Thomas Guides are a commonly available street atlas providing city guides and street names in map form for each major metropolitan area.

Referring to the SCAG's area type map (Figure 4-1), VRC classified Thomas Guide (TG) pages of Ventura, Los Angeles, Orange, Riverside, and San Bernardino counties into three area types: U, S, and R. Only those TG pages which contain at least one school per page were compiled for each area type. Over the five county region, there were 114 TG pages containing at least one school for "urbanized" areas. These pages for urbanized areas were all clustered in the counties of Los Angeles (with 96 pages) and Orange (with 18 pages). TG pages for "small urban" areas were distributed rather evenly over the five counties: 32 pages in Ventura, 8 in Los Angeles, 29 in Orange, 30 in Riverside, and 28 in San Bernardino. School-containing TG pages for "rural" areas were found in the counties of Los Angeles (with 11 pages), Riverside (20), and San Bernardino (20).

For each area type, a series of random numbers were generated to select particular TG pages with school(s) and designate a specific location on each selected page. Five digit random numbers were used for "urbanized" and "small urban" areas to designate a TG page by the first 3-digits and the row and column of the page by the last 2-digits whereas 4-digit random numbers were used for "rural" areas to designate a TG page by the first 2-digits and the location in the page by the last 2-digits. On each selected page, a public school nearest to the random-number-designated location was selected as a candidate school for a chase car survey. Private schools were excluded from this selection process due to anticipated difficulties in identifying the school names and obtaining information on their school bus routes and schedules.

Twenty-three (23) candidate schools were selected for "urbanized" areas of the five county region. Table 4-6 lists these candidate schools and their locations. VRC contacted each candidate school or its school district office to obtain specific information on the school bus routes and schedules. Only one school bus route per school was used for chasing the school bus by driving a datalogger-equipped car once in the morning and once in the afternoon. Among the 23 candidate schools, the 14 schools for which the school bus routes and schedules were obtained were used as target schools for conducting a chase car survey.

Table 4-7 lists 23 candidate schools in "small urban" areas and 14 target schools whose bus routes were used for the chase car survey. Table 4-8 lists 13 candidate schools and 7 target schools for "rural" areas.

Table 4-6. LOCATIONS OF 23 CANDIDATE SCHOOLS AND 14 TARGET SCHOOLS USED FOR SCHOOL BUS CHASES IN "URBANIZED" AREA

TG Page	School Type	Street/X-Street	School District	Chase Car Study	
				Used?	Route No.
LA41-4C	ELEM[a]	ARMACOST AVE/RCHSTR AVE	L.A. U.	Yes	5245
LA78-5D	ELEM	ANCHOVY AVE/25TH ST	L.A. U.	Yes	2558
LA90-3F	ELEM	HARRISON AVE/SUMMER AVE	POMONA U.	No	
OR20-4F	MARINA HS[b]	EDINGER AVE/SPRINGDALE ST	HUNTINGTON U.H.	Yes	55
OR23-3B	ELEM	MCFADDEN AVE/SYCAMORE ST	SANTA ANA U.	Yes	
LA40-5E	ELEM	ENTRADA DR/OCEAN AVE	L.A. U.	Yes	5124
LA50-6D	ELEM	OSAGE AVE/OLAND AVE	INGLEWOOD U.	No	
LA64-2F	ELEM	ROSECRANS AVE/ACASIA AVE	COMPTON U.	No	
LA83-4D	ELEM	KENWOOD AVE/SOMERSET ST	BUENA PARK ELEM.	Yes	56
OR1-6F	ELEM	IMP. HWY/SCHOOLWOOD DR	LA HABRA CITY	Yes	9
LA7-3F	ELEM	MAYALL ST/RUFFNER AVE	L.A. U.	Yes	4341
LA15-3D	FULTON JR HS[c]	KESTER AVE/SATICOY ST	L.A. U.	Yes	780
LA28-2D	ELEM	LAUREL AVE/CANON AVE	ARCADIA U.	No	
LA36-5E	ELEM	BUDAU AVE/CRONUS ST	L.A. U.	No	
LA44-3B	ELEM	OLYMPIC BL/GRATTAN ST	L.A. U.	No	
LA56-3E	ELEM	98TH ST/ISIS AVE	L.A. U.	Yes	2310
OR9-2F	ELEM	ARNOLD WY/HOLDER ST	BUENA PARK ELEM.	Yes	60
OR26-2F	ELEM	FINCH AVE/REDWOOD ST	FOUNTAIN VALLEY	Yes	10
LA16-6E	ELEM	OXNARD ST/CLEON AVE	L.A. U.	Yes	4705
LA57-2F	BRET HARTE JR HS	HOOVER ST/92ND ST	L.A. U.	No	
LA74-4D	ELEM	YOUNG ST/MAHAR AVE	L.A. U.	Yes	126
OR10-5A	JR HS	ORANGE AVE/KNOTT AVE		No	
LA16-3D	WYANDOTTE JR HS	BAKMAN AV/VALERIO ST	L.A. U.	No	

[a] Elementary school, [b] High school, [c] Junior high school

Table 4-7. LOCATIONS OF 23 CANDIDATE SCHOOLS AND 14 TARGET SCHOOLS USED FOR SCHOOL BUS CHASE IN "SMALL URBAN" AREA

TG Page	School Type	Sreet/X-Sreet	School District	Chase Car Study Used?	Chase Car Study Bus No.
LA124-4C	ELEM	SECO CYN RD/PARAGON DR	SAUGUS U.	Yes	16
RV12-5B	ELEM	COLORADO AVE/JACKSON ST	RIVERSIDE U.	Yes	4
RV45-6E	ELEM	IRWIN ST/SHAVER ST	SAN JACINTO U.	Yes	3
SB11-2C	ELEM	VETERANS CT/13TH AVE	UPLAND U.	Yes	1A
SB14-4B	ELEM	OLEANDER AVE/ORANGE WY	FONTANA U.	Yes	11
LA111-6F	ELEM	MORNING DR/VIA CARRILLO		No	
OR12-6D	ELEM	BRIARDALE AVE/PALMDALE AVE	ORANGE U.	No	
OR35-2F	ELEM	VALLEY PKWY/ADELANTO DR	CAPISTRANO U.	Yes	160
RV21-3E	ELEM	STRATION DR/LOMA DR	RIVERSIDE U.	No	
RV151-5C	ELEM	MAPLE AVE/7TH ST	BEAUMONT U.	No	
SB31-6A	ELEM	8TH ST/REEDY WOODS LN	YUCAIPA-CALIMESA U.	Yes	17
VN48-5E	ELEM	LOMA VISTA RD/LINN DR	VENTURA U.	Yes	1
VN60-2B	RIO MESA HS	CENTRAL AVE/STRICKLAND DR	VENTURA CO.	Yes	22
VN74-2D	ELEM	AVD DE LOS/CL BOUGANVILLA	CONEJO VALLEY U.	Yes	15
VN87-4B	CONT HS	AGOURA RD/LEWIS RD	LAS VIRGENES U.	No	
LA127-3C	WM.S. HART HS	NEWHALL RD/14TH ST		No	
OR29C-1E	LAGUNA HLS HS	LAGUNA HILLS DR/PASEO DE VALENCIA	SADDLEBACK VALLEY U	Yes	1
SB2-3E	ELEM	JASPER ST/BEECHWOOD DR	CENTRAL	No	
SB14-2F	ELEM	MILLER AVE/MAPLE AVE	FONTANA U.	Yes	16
SB27-4C	ELEM	KENTFIELD/ORIOLE WY	COLTON U.	Yes	47
VN61-6F	ELEM	TEMPLE AVE/HARTNELL ST	PLEASANT VALLEY	Yes	300
OR29D-2F	ELEM	NUBLES/LA FUENTE	SADDLEBACK VALLEY U.	No	
RV6-4E	ELEM	PACIFIC AVE/45TH ST	RIVERSIDE U.	No	

Table 4-8. LOCATIONS OF 13 CANDIDATE SCHOOLS AND 7 TARGET SCHOOLS USED FOR SCHOOL BUS CHASE IN "RURAL" AREA

TG Page	School Type	Street/X-Street	School District	Chase Car Study	
				Used?	Bus No.
LA159-9A	QUARTZ HILL HS	LYRIC AVE/59TH ST	LANCASTER	Yes	1219
SB333-2C	ELEM	GOSHUTE AVE/PIONEER RD	APPLE VALLEY U.	Yes	22C
SB334-4E	ELEM	MAPLE AVE/MAUNA LOA ST	HELENDALE U.	No	
SB360-4A	SERAND HS	SUNNY SLPE RD/SHEEP CRK RD	MT. BALDY JT. U.	Yes	23
RV191-2C	CONT HS	MEQUITE AVE/MTN VIEW DR	PALM SPRINGS U.	Yes	14
RV206-6A	ELEM	DILLON AVE/RUBY AVE	DESERT SANDS U.	No	
RV214-5E	ELEM	50TH AVE/DATE PALM DR	DESERT SANDS U.	No	
RV216-6D	ELEM	7TH ST/PENDELTON WY	COACHELLA VALLEY U.	Yes	2
RVZ26-1D	ELEM	VALLEY RD/HARRISON ST	COACHELLA VALLEY U.	Yes	16
LA174-8J	ELEM	AVE Q/160TH ST	LANCASTER U.	Yes	4463
SB244-6D	ELEM	ASH RD/MAIN ST	BARSTOW U.	No	
SB245-1C	ELEM	CAMIRILLO AVE/TORRES AVE	BARSTOW U.	No	
SB247-5A	JR HS	ARMONY RD/MCBROOM AVE	BARSTOW U.	No	

4.2 EXECUTION OF CHASE CAR STUDY

VRC purchased two vehicle data logging devices with sensors for vehicle speed and installed them to company vehicles. The data loggers are capable of recording travel time spent in each speed range (i.e., idle, 1-5, 6-10,..., 50-55, and >55 mph) and each of a few acceleration ranges (i.e., <-2, -2 to 0, cruising, 0 to 2, >2 mph/sec).

For purposes of scheduling, routes were grouped into broad geographic areas: Central Los Angeles, South Bay, San Fernando and Santa Clarita Valleys, Antelope Valley, San Gabriel Valley, San Bernardino County, Riverside County, North Orange County, South Orange County, Ventura County. Weekday scheduling typically included one school bus route, "chased" twice over the course of the day with transit routes mixed before, after, and in between the school bus chases. Weekend scheduling did not include school buses or peak/off-peak considerations. Therefore, scheduling depended primarily on location and on the availability of chase car drivers.

4.2.1 CHASE SCHEDULING

The survey design discussed in Section 4 detailed how the bus service routes were selected for three area types (urbanized, small urban, and rural) and for six time periods (WD-peak-hour, WD-off Peak, Saturday, and Sunday for transit bus; and WD-morning and WD-afternoon for school bus). By adhering to the survey design, the spatial representativeness of bus driving patterns would be assured for each area type and time period in the present chase car study. However, the survey design does not provide any assurance to yield representative driving patterns data during each time period from a few truncated observations of the proposed 30-minute bus chases with an instrumented chase car.

Therefore, the chase car drivers were instructed to adhere to the following bus-chase segment selection guidelines to the extent possible:

(A) The chase starting times should be scattered, to the extent possible, over the entire duration of each time period (e.g., 0600-0900 and 1500-1800 for WD-peak hour); and

(B) The actual chase periods should be selected so as to cover the entire lengths of bus service routes at approximately the same probability.

Both guidelines were somewhat too idealized to be observed in actual bus chases. For example, Guideline A was nearly impossible to be attained for school buses because the great majority of them depart at about the same time. Guideline B was easier to follow but caused unproductive time on the part of chase car drivers. Nevertheless, the drivers were encouraged to capture bus

driving patterns data for the entire segments of bus service routes by staggering 30-minute long chases over the initial, middle, and end portions of the service routes.

Transit buses - SCRTD and most other large transit bus operators were pre-contacted as to the nature of the study and the scheduled chases. Several of the larger operators were also sent a request for cooperation letter signed by the ARB contract manager. Depending upon the level of pre-contact, drivers of the selected buses were usually briefly informed by the chase car driver as to the nature of the study. An attempt was made to meet buses as they arrived at scheduled stopping points along their routes. This enabled the recording of initial idling data as well as an opportunity for the chase car driver to identify himself, his car, and the purpose of the study. Informative leaflets were designed and handed to the bus drivers and other interested transit personnel (see Appendix D for chase car driver material). The bus drivers were instructed to drive as normal, but to be aware that the bus would be followed for about 30 minutes.

School buses - School district contacts were generally notified twice as to the chases, in addition to contacting the bus driver immediately before the chase. The district was first contacted for its route information and then later re-contacted a few days prior to the scheduled chase to ensure the buses were operating as scheduled. The chase car driver followed the same identification procedure with the school bus driver as described above for transit bus drivers. The school buses were usually met at points where intersecting the selected schools would occur within the duration of the chase and where there would be a few minutes to communicate with the bus driver (usually at a school location).

4.2.2 CONDUCTING A CHASE

Trip Log - Each chase car driver kept a trip log in which the following information was written for each trip: type of trip (transit, school, or other), trip date, transit route number or school name, trip start time, trip start location, transit line or school district, bus description (approximate length, style and, where possible, manufacturer), number of service stops (hand-held tally counter reading), trip end time, trip end location, and miles traveled. Any unusual occurrences during a trip were footnoted and described on back of the log sheet. Each trip log sheet has 13 blank lines corresponding with the 13 maximum trips recorded by the datalogger. Any time the datalogger's accumulated statistics were reset, a new trip log sheet was started with the data file name being recorded on the upper right hand corner of the trip log sheet.

Datalogger - The datalogger can record statistics characterizing up to 13 trips, or approximately 2-3 days of bus chases (for data security the datalogger was downloaded as often as possible, averaging about 3 trips per file). The study drivers downloaded each set of data (in both text-bearing and strictly numerical formats), checked the data files (the text-bearing format was conducive to this kind of visual inspection of the data), made backup copies, and reset the

datalogger's accumulated statistics by selecting that option from the datalogger's menu. A sample output of bus driving pattern data measured and processed by the datalogger system is shown in Figure 4-2.

Driving - The chase car driver turned on the datalogger as soon as the bus began idling. The trip duration goal was 30 minutes from the time the selected bus moves forward to begin its trip. The chase car followed the bus at a distance allowing for safe stopping but close enough so as not to lose the bus at intersection or in front of other vehicles. When the bus pulled over to load or unload passengers, the study driver attempted to stop right behind the bus unless this meant blocking an intersection or a busy driveway. In these cases the study driver either stopped farther behind the bus if the stop was anticipated or continued on in front of the bus until there was a safe place to pull over. Once the chase car driver reached the target chase duration, he turned off the datalogger and pulled over as soon as possible to complete the trip log. If, for some reason, the chase car driver accidentally turned off the datalogger before the trip was completed, the datalogger possessed an approximately 5-second delay period when its red light would blink. During this period the datalogger could be turned back on for the recording of data for the same trip to resume. We used this feature during some test drives but did not use it at all during actual bus chases.

4.3 COMPILATION AND ANALYSIS OF BUS DRIVING PATTERN DATA

4.3.1 DEVELOPMENT OF CHASE CAR DATABASES

After all chase car surveys on transit and school buses were completed, the driving pattern data acquired by the data logger system installed in the chase cars were downloaded into the VRC computer system. Raw driving pattern data were converted into an ASCII format compatible with the VRC database software, Paradox. The driving pattern data acquired by the datalogger was supplemented with the trip log data which were recorded by chase car drivers during all bus chases.

Two databases were developed from the chase car study: one containing survey information on subject buses, chase date and times, and bus chase locations; and the other containing actual driving pattern data such as time spent in acceleration, cruising, and idling and total trip distance for each bus chase trip. The latter data were all recorded by the dataloggers while the former data were recorded by chase car drivers.

The data records of the two databases were interlinked by common identifiers such as trip number and chase date/time. These linked records in a relational database format simplified analysis of the bus driving pattern data gathered by the chase car study.

Trip # 2 of 4
trip date: 93 / 4 / 29 trip time 7 : 48 total trip distance 7.8 miles
Speed Dist'n By Acceleration (cumulative seconds)

Speed Range	Acceleration Ranges MPH<-2	-2..-.25	-.25...25	.25..2	>2
0 -	4	40	55	20	46	20
5 -	9	35	47	28	42	43
10 -	14	43	64	34	67	47
15 -	19	19	72	38	65	38
20 -	24	16	79	71	81	27
25 -	29	2	87	92	103	6
30 -	34	0	34	33	47	2
35 -	39	0	5	2	5	1
40 -	44	0	0	0	0	0
45 -	49	0	0	0	0	0
50 -	54	0	0	0	0	0
>	55	0	0	0	0	0

Idle Cell	Cum Sec	No. Events
< 10 sec	74	21
10-60 sec	289	12
> 60 sec	380	3

Trip # 3 of 4
trip date: 93 / 4 / 29 trip time 14 : 31 total trip distance 6.2 miles
Speed Dist'n By Acceleration (cumulative seconds)

Speed Range	Acceleration Ranges MPH<-2	-2..-.25	-.25...25	.25..2	>2
0 -	4	32	52	21	38	13
5 -	9	29	57	32	34	36
10 -	14	25	76	30	42	36
15 -	19	21	54	21	66	26
20 -	24	9	72	75	65	19
25 -	29	3	52	51	58	5
30 -	34	0	32	35	40	2
35 -	39	0	2	9	7	0
40 -	44	0	0	0	0	0
45 -	49	0	0	0	0	0
50 -	54	0	0	0	0	0
>	55	0	0	0	0	0

Idle Cell	Cum Sec	No. Events
< 10 sec	72	18
10-60 sec	218	11
> 60 sec	806	3

Figure 4-2. Sample Output of Bus Driving Pattern Data Measured and Processed by the Data Logger System Installed in Chase Cars

4.3.2 STATISTICAL ANALYSIS OF BUS DRIVING PATTERN DATA

Summary statistics of bus driving pattern data were computed for each of the area type/time period combinations studied in the chase car survey (see Table 4-1). Table 4-9 presents summary statistics of transit bus driving pattern data acquired by instrumented chase cars. The driving patterns were characterized using the following parameters:

trip distance	=	total distance following the target bus by the instrumented chase car
trip duration	=	total duration of the bus following while the datalogger was turned on,
trip speed	=	average speed over the entire trip including the time spent in idling,
driving speed	=	average speed while the bus is in motion, excluding the time in idling,
service stops	=	the number of bus service stops during the chase,
idling events	=	the number of idling events the bus experienced during the chase, and
time fraction	=	fraction of the total trip time during which the bus was in one of the four driving modes -- hard acceleration ($\geq$2 mph per second), cruising (-2<accel<2 mph/s, hard deceleration ($\leq$-2 mph/s), and idling.

In the table, the parameter values are computed not only for transit bus driving pattern data in each area-type/time period combination but also for the Federal Test Procedure (FTP) driving cycle data which were kindly furnished to VRC by ARB's Mobile Source Division. Both the average trip distances and trip durations attained in the bus chases happened to be quite similar to the ones used in the FTP, 7.5 miles and 31.2 minutes. Another similarity between FTP and transit bus driving patterns is that both driving patterns exhibit about the same time fractions in hard acceleration and hard deceleration, namely around 9 percent of the total trip duration each.

Dissimilarities between the FTP cycle and the transit bus driving patterns are found in driving speed and idling. Transit buses tend to spend more time in idling and less time in cruising than those reflected in the FTP driving cycle: about 30 percent of the trip driving in idling and 47-54 percent in cruising vs 19 percent and 63 percent respectively in FTP. For urbanized areas, during the weekday peak hours, the transit bus average trip speed, 14.3 mph, is nearly the same as the FTP average trip speed of 14.4 mph. However, the average driving speed of transit buses is considerably higher than that of FTP: 20.7 mph vs 17.9 mph. This trend of higher driving speed for transit buses as compared to the FTP values is seen in other area-type/time period combinations as well.

Table 4-9. SUMMARY STATISTICS OF **TRANSIT** BUS DRIVING PATTERN DATA ACQUIRED BY THE CHASE CAR STUDY

Data Item	FTP Test Cycle*	Urbanized Area				Small Urban Area		
		WD-Peak	WD-Off P.	Sat.	Sun.	WD-Peak	WD-Off P.	WKEND
No. of Chase Trips (-)	UNK	30	30	12	12	20	20	16
Avg. Trip Distance (mi)	7.5	7.0	7.6	7.8	8.2	8.9	9.4	8.0
Avg. Trip Duration (min)	31.2	29.3	29.5	30.0	30.0	31.4	31.9	30.0
Avg. Trip Speed (mph)	14.4	14.3	15.4	15.7	16.6	17.0	17.8	15.9
Avg. Driving Speed(mph)	17.9	20.7	21.8	22.2	23.4	24.4	24.9	23.6
No. of Service Stops (-)	UNK	15.9	15.1	15.7	13.7	8.6	8.4	7.1
No. of Idling Events (-)	22.0	30.7	31.8	27.8	24.6	26.0	22.5	22.6
Time Fraction of:								
Hard Accel (-)	.09	.11	.11	.09	.08	.09	.09	.09
Cruising (-)	.63	.47	.49	.54	.54	.51	.53	.51
Hard Decel (-)	.09	.10	.10	.08	.08	.09	.09	.08
Idling (-)	.19	.32	.30	.30	.30	.31	.29	.33

* LA-4 cycle (i.e., Bag 1 and 2 portions of the FTP) was used.

In summary, transit buses idle more frequently and in longer duration than the FTP cycle. Although the overall trip speeds are about the same as the FTP's, their average driving speeds are considerably higher than the FTP. Both factors appear to result in higher emissions if the actual bus driving patterns were incorporated in emission test protocols.

Table 4-10 presents summary statistics of school bus driving pattern data acquired using instrumented chase cars. School bus driving patterns have both similarities and dissimilarities to those of transit buses. A large time fraction of idling (~30% of total trip duration) is common to both transit and school buses. However, the numbers of idling events and service stops are considerable fewer for school buses than for transit buses.

The school bus driving patterns noticeably change from urban areas (including both "urbanized and "small urban") to rural areas. Both the average trip speed and driving speed for "urbanized" and "small urban" areas are much lower than those of rural areas (e.g., about 17 mph in urban areas vs about 30 mph in rural areas). The percentage of idling in total trip duration for "urbanized" and "small urban" areas is 31% while that for rural areas is about 20%. On the other hand, the number of service stops is greater in rural areas than in urban areas: 7-10 vs. 4-7.

Table 4-11 compares distributions of driving time and VMT over the speed ranges in the FTP driving cycle with those of actual driving patterns of transit and school buses in urbanized areas. The conversion from driving time distributions to VMT distributions was made in the following manner:

Time fraction: $f_{si} = t_{si} / T$ (1)

VMT fraction: $g_{si} \sim t_{si} v_{si} / L$ (2)

$g_{si} \sim f_{si} v_{si} (T/L)$ (3)

where T = total trip duration
L = total trip distance
t_{si} = time spent in the i-th speed range s_i
v_{si} = mid-range vehicle speed over the i-th speed range

Using the approximate equation, Eq. (3), VMT fractions of various speed ranges were computed from measured time fractions and the trip duration and distance values for each bus chase trip.

Table 4-11 shows that the speed profile (given by VMT fraction in each speed bin) of the FTP cycle is a bimodal distribution having the first peak in the 25-29 range and the second peak in the 50-54 mph range. In contrast, the speed profile of transit bus driving patterns is a unimodal distribution having the single peak in the 25-29 mph range. The school bus driving pattern

Table 4-10. SUMMARY STATISTICS OF SCHOOL BUS DRIVING PATTERN DATA ACQUIRED BY THE CHASE CAR STUDY

Data Item	FTP Test Cycle*	Urbanized		Small Urban		Rural	
		WD-AM	WD-PM	WD-AM	WD-PM	WD-AM	WD-PM
No. of Chase Trips (-)	UNK	14	14	14	14	7	7
Avg. Trip Distance (mi)	7.5	8.2	7.8	7.3	7.6	11.7	10.4
Avg. Trip Duration (min)	31.2	29.5	27.4	25.6	25.9	25.4	28.0
Avg. Trip Speed (mph)	14.4	16.3	17.5	16.4	17.0	27.1	22.6
Avg. Driving Speed(mph)	17.9	23.2	24.0	23.6	24.3	32.7	28.9
No. of Service Stops (-)	UNK	4.0	3.6	6.0	7.0	6.7	9.6
No. of Idling Events (-)	22.0	22.6	20.8	17.2	16.5	12.6	18.2
Time Fraction of:							
Hard Accel (-)	.09	.11	.10	.08	.08	.09	.10
Cruising (-)	.63	.48	.50	.54	.54	.62	.58
Hard Decel (-)	.09	.10	.09	.07	.07	.09	.10
Idling (-)	.19	.31	.31	.31	.31	.19	.22

* LA-4 cycle (i.e., Bag 1 and 2 portions of the FTP) was used.

Table 4-11. COMPARISON OF DISTRIBUTIONS OF DRIVING TIME AND VMT OVER SPEED RANGES FOR FTP DRIVING CYCLE AND ACTUAL DRIVING PATTERNS OF TRANSIT BUS AND SCHOOL BUS DURING WEEKDAY PEAK HOURS IN URBANIZED AREA

Speed/Idle Range	Mid-Range Speed	FTP Driving Cycle			Transit Bus		School Bus	
		Time Frct.	VMT Frct.	Norm VMT Fr	Time Frct.	VMT Frct.	Time Frct.	VMT Frct.
Idle<10s	0.0	.02	.00	.00	.04	.00	.02	.00
10-60s	0.0	.18	.00	.00	.20	.00	.14	.00
Idle>60s	0.0	.00	.00	.00	.07	.00	.14	.00
0-4 mph	2.5	.05	.01	.01	.05	.01	.04	.01
5-9 mph	7.5	.05	.03	.02	.08	.04	.07	.03
10-14 mph	12.5	.05	.04	.03	.09	.08	.08	.06
15-19 mph	17.5	.09	.11	.07	.09	.11	.08	.08
20-24 mph	22.5	.15	.24	.16	.10	.17	.09	.13
25-29 mph	27.5	.18	.33	.23	.11	.20	.10	.16
30-34 mph	32.5	.08	.17	.12	.08	.18	.09	.19
35-39 mph	37.5	.05	.13	.09	.04	.11	.06	.14
40-44 mph	42.5	.01	.02	.01	.02	.05	.03	.07
45-49 mph	47.5	.03	.09	.06	.01	.03	.01	.03
50-54 mph	52.5	.05	.20	.13	.00	.01	.03	.08
>=55 mph	60.0	.03	.11	.08	.00	.01	.01	.04
Total:		1.00	1.48	1.00	1.00	1.01	1.00	1.01

___ Either the first peak of a bimodal distribution or the single peak of a unimodal distribution.

_ _ The second peak of a bimodal distribution.

exhibits a weak bimodal distribution having the strong first peak in the 30-34 mph range and the weak second peak in the 50-54 mph range.

Figures 4-3 through 4-5 show, respectively, the driving patterns of FTP, urban transit buses and urban school buses in terms of the fractions of time spent in each speed and idle durations range. The FTP driving cycle has the feature of a distinct bi-modal speed distribution, which is characteristic of a combined cycle of both surface street and highway driving patterns. The driving pattern of transit buses in "urbanized" area during the weekday peak hours is characterized by the uni-modal speed distribution and the frequent and extended (>60 s) idling events. The driving pattern of school buses in urbanized areas is quite similar to that of transit buses with two exceptions: the second peak in th speed distribution in the 50-54 mph range, and the prevalence of extended (>60 s) idling events.

A complete set of tables showing both driving time and VMT distributions over speed ranges are given in Appendix E. Summary statistics of FTP cycle and actual bus driving pattern data are given in Appendix F.

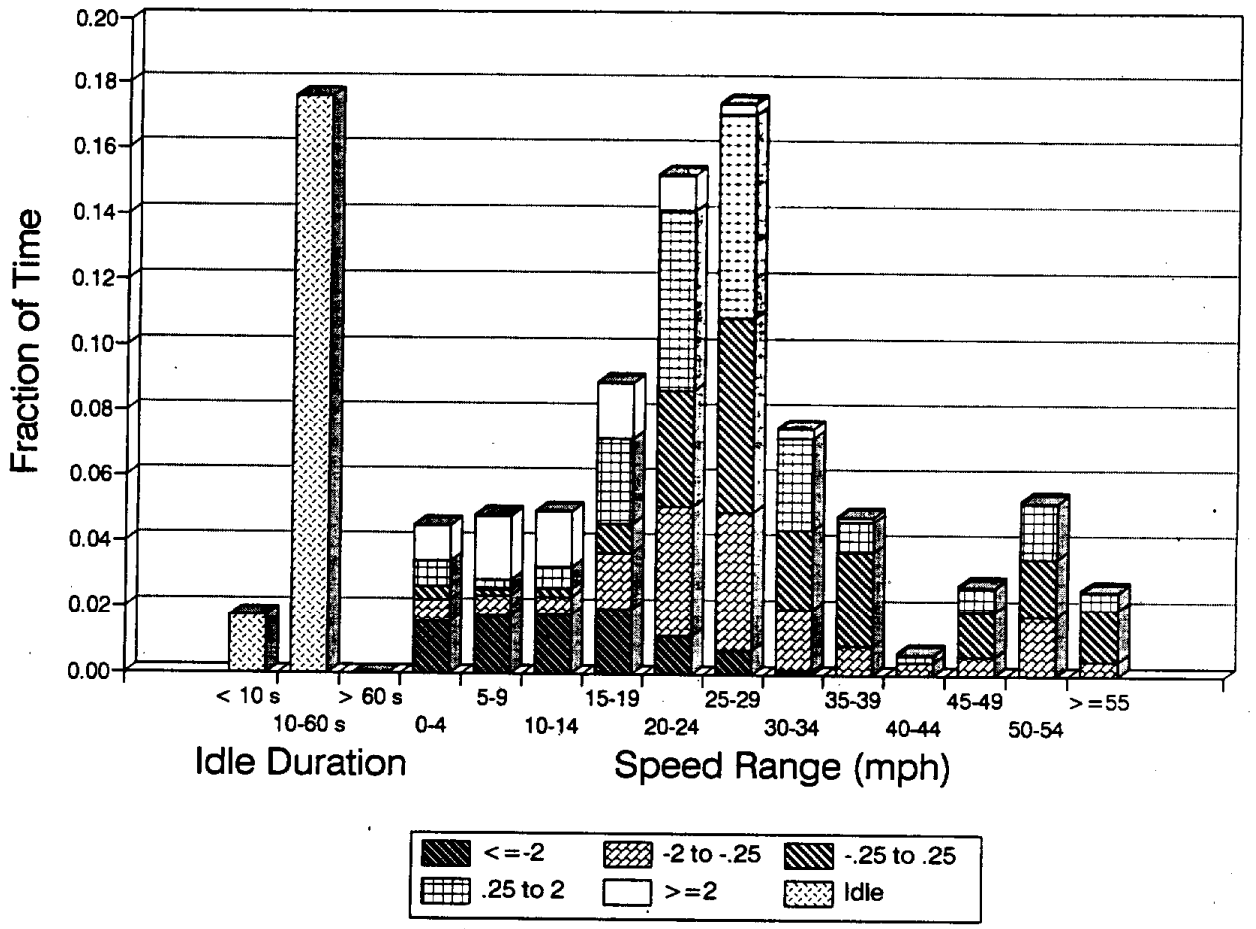

Figure 4-3. Distribution of Driving Mode Used in the FTP-75 Test Driving Cycle (Bags 1 and 2 only)

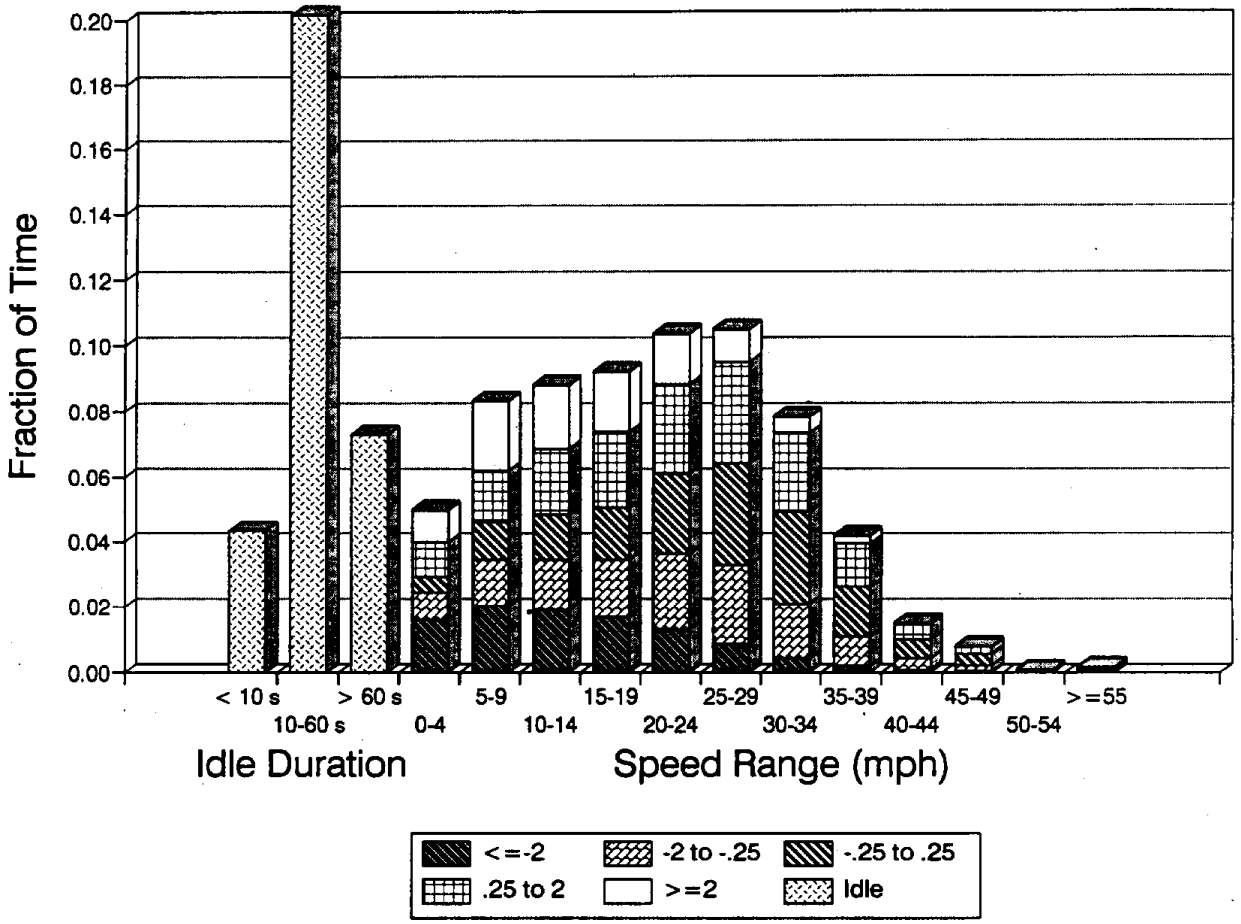

Figure 4-4. Distribution of Driving Modes for Transit Bus in Urbanized Area during WD Peak Hours (n=30)

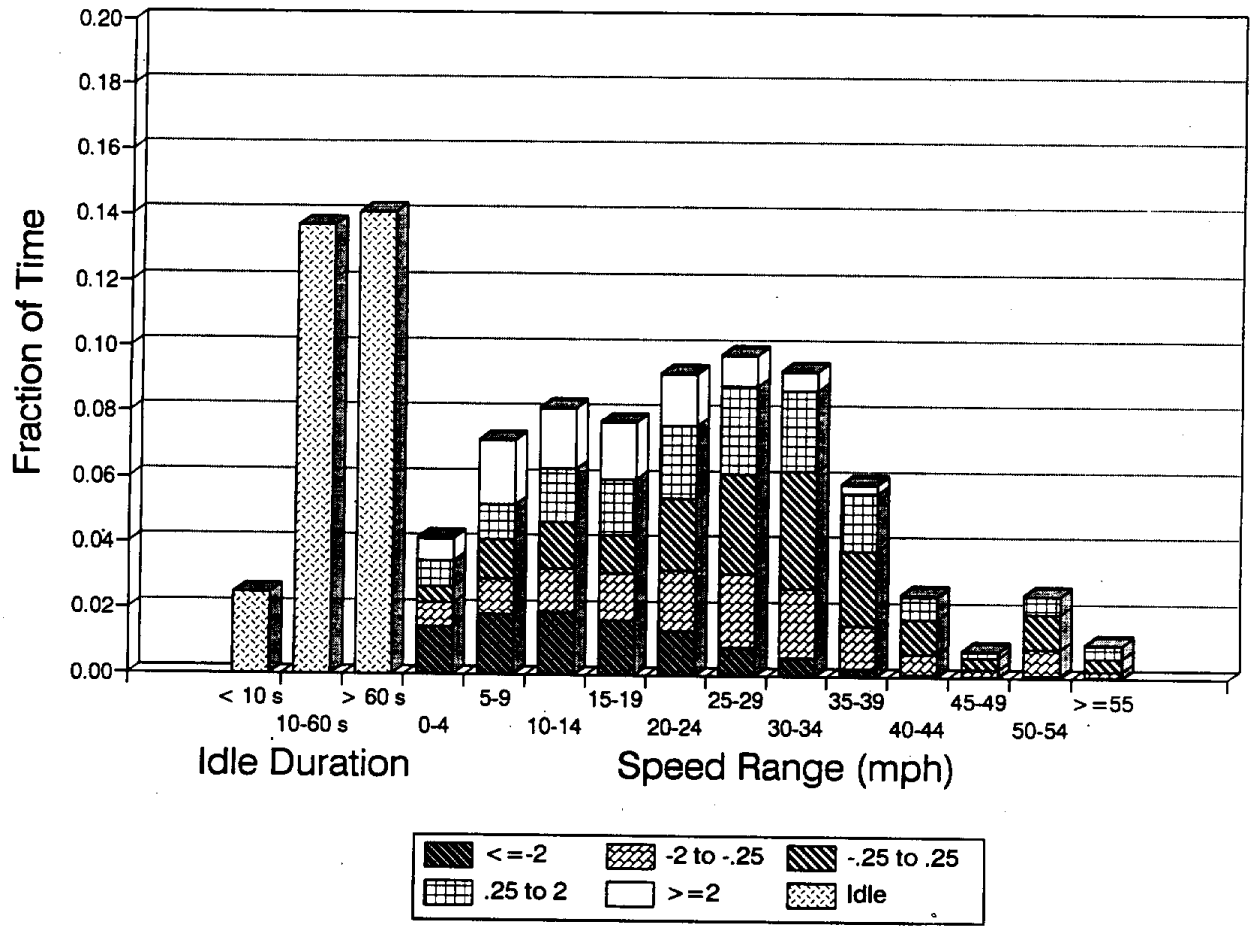

Figure 4-5. Distribution of Driving Modes for School Bus in Urbanized Area during WD Morning Hours (n=14)

5.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The ARB's emission factor model, EMFAC, categorizes on-road motor vehicles into 6 vehicle classes: motor cycle, auto, LDT, MDT, HDV, and bus. HDV has three subcategories: LHDV, MHDV, and HHDV. Autos are passenger vehicles while LDT, MDT, HDV, and buses are all trucks in the broad sense. LDT, MDT, and HDV are classified according to each truck's gross vehicle weight (GVW) while buses are differentiated from the other trucks because of their unique use function: carrying many passengers and operating on a schedule. Therefore, buses can have all 5 weight classes, LDT through HHDV.

Conventional buses are large in size and operate on a fixed schedule. However, there are many other buses such as those operating on a demand-response basis instead of a fixes schedule and smaller buses whose sizes and use patterns are similar to those of van-pool vans and limousines. Therefore, it is not possible to define "bus" in a clear-cut manner as in the definitions for the other vehicle classes.

This study followed the bus definitions used in the Federal Transit Administration and the California Vehicle Code which list 7 bus types: transit bus, general public paratransit vehicle, bus, school bus, school activity bus, youth bus, and farm labor vehicle. After considering the trade-offs between anticipated effort requirements and expected benefits, the following vehicle types were excluded from consideration under this study:

- Inter-city bus
- Charter bus
- Farm labor vehicle
- Vehicles owned or operated by small transit operators not included in either the FTA database or the APTA directory.

The bus population included in this study consists of transit buses listed in the national databases (FTA and APTA) and school buses accounted for in the CHP database. Because of the exclusion of the buses listed above, the total number of buses identified in the present study is somewhat fewer than the numbers quoted by DMV and the Caltrans study (1992)*. The bus population investigated under this study , however, includes many types of buses such as small-to-medium gasoline-fueled buses, alternative fuel buses, as well as large diesel buses, only for which the current EMFAC model provides the emission factors.

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*"Public Transportation Alternative Fuels - A Perspective for Small Transportation Operations," California Department of Transportation (1992), Prepared by Booze-Allen & Hamilton.

Although these databases (FTA,APTA and CHP) were useful for determining the statewide fleet sizes for transit buses and school buses, the databases alone were not adequate for determining bus' attributes such as weight class, vehicle age, fuel type and primary place of operation, all of which were needed for this study. To obtain such information and general use pattern of buses, Valley Research Corporation conducted three supplementary surveys: school district survey, school bus contractor survey and bus manufacturer survey.

The school district and bus contractor surveys were completed with high response rates (67% and 88%, respectively). The bus fleet and use pattern data obtained from the surveys were used to determine the vehicle age distribution, the fuel type mix, and the spatial assignment of buses to individual counties. The bus manufacturer survey yielded much-needed data of bus specifications for various bus models. The specification data such as GVW, total length, and seating capacity were used to derive a regression relationship between GVW and total length for transit buses, and an empirical relationship between weight class and seating capacity for school buses. The two relationships were then applied to determine the correct weight class for each bus from the two routinely available data items: total bus length and maximum seating capacity.

The present EMFAC emission factors for buses are derived from engine dynamometer test data of the FTP cycle designed for heavy duty trucks. Bus driving patterns are different from those of typical trucks: making many stops and idling a lot for passenger loading and unloading. To determine a representative driving pattern or patterns for buses, a field survey was designed and conducted by following buses for about 30 minutes each with datalogger-equipped chase cars. The second-by-second driving data were obtained for transit and school buses over 210 different service routes selected from urban, small urban and rural areas of the Southern California.

Major findings and conclusions of the present study are as follows:

Transit Buses

- Using the FTA database and the APTA directory, VRC identified 8,631 active transit buses operating in the state in 1990 and additional 740 inactive buses -- those used only for emergencies or remaining totally inactive during the year.

- Statewide transit bus VMT was estimated to be 311 million miles per year or 36,000 miles per year per active bus.

- Both buses and bus VMT were allocated first to correct ARB weight classes (i.e., MDT, LHDV, MHDV, HHDV) using the regression relationship, and then to fuel types and individual counties.

- Among the 12 categories defined by 4 weight classes and 3 fuel types, diesel-

fueled HHDV buses account for by far the largest percentages in both bus population and VMT: 72 percent of the bus population and 76 percent of the annual VMT.

- Buses that run on fuels other than gasoline and diesel account for a rather modest share in both bus population and VMT: 6 percent of the population and 4 percent of the statewide bus VMT.

School Buses

- The statewide school bus population is 23,900 buses, which is twice the transit bus population. Annual school bus VMT is 317 million vehicle miles statewide or 13,000 miles per bus.

- Diesel buses account for a great majority of the statewide bus population (81%) and VMT (84%). Gasoline buses comprise most of the remaining population and VMT, leaving practically none for other fuel buses.

- HHDVs weighing over 33,000 pound GVW account for over half of the statewide bus population and VMT while LHDVs weighing less than 14,000 pounds GVW account for about a third of the population and VMT.

- For school buses, mileage accrual rates are higher for LHDV buses (16,000 mi/y) than for HHDV buses (12,500 mi/y). Contractor buses exhibit considerably higher accrual rates (19,000) than either public school buses (13,000) or private school buses (9,200).

- The median age of contractor buses is considerably lower than public school buses (4 years vs 11 years). For both contractor and public school buses, the mileage accrual rate does not decrease much with vehicle age, in contrast to automobiles. Buses are typically retired or rebuilt when they become unfit for regular service.

- School buses are driven predominantly on weekdays (98%), on urban surface streets (51-76%), and for home-to-school trips (68-74%). Deadhead miles account for 21% of total VMT for public school buses and 11% for contractor buses. Activity trips account for about 10% of VMT for both public school and contractor buses.

Bus Driving Patterns

- Transit buses idle more frequently and in longer duration than the FTP cycle. Although the overall trip speeds are about the same as the FTP's, their average driving speeds are considerably higher than the FTP: 20.7 mph vs 17.9 mph.

- A large time fraction spent in idling -- about 30% of total trip duration -- is common to both transit buses and school buses. The numbers of service stops and idling events are 15-16 and 31-32 respectively for transit buses on weekday, and for school buses, 3.5-4 and 21-23 respectively in rural areas.

- The school bus driving patterns varied from urban areas to rural areas. Both the average trip speed and driving speed for "urbanized" and "small urban" areas are much lower than those of rural areas: 16-17 mph and 23-24 mph in urban areas vs. 23-27 mph and 29-33 mph.

- While the speed profile of the FTP cycle exhibits a strong bimodal distribution having the first peak in the 25-29 mph range and the second peak in the 50-54 mph range, the actual bus driving patterns are either unimodal (for transit buses) or weak bimodal (for school buses).

The primary data sources used for this study came from FTA for transit buses and CHP for school buses. There are two other data sources: alternative fuels study by Caltrans, and DMV bus registration summary. The Caltrans study (1992) covered many small transit operators and thus could be used as a supplementary data source for transit buses. However, the authors suspected that the study included not only buses but also bus-like vehicles such as van-pool vans and limousines. The DMV bus registration statistics may be the most inclusive of all types of buses defined in the California Vehicle Code. However, according to a statistician in the DMV's Registration Division, the bus statistics are the least reliable among various DMV statistics of registered vehicles. It merely provides a total count of bus registration over a 12-month period, without any breakdowns by type of bus or by active/inactive basis.

By contrast, the FTA and CHP databases provide fleet-based bus data which are essential for developing highly resolved estimates of bus population and activity with respect to weight class, fuel type, vehicle age, and county of operation. Another advantage of using the two data bases is that they are annually updated. This assures that a future update of the present study data can be made easily and regularly.

The methodology of determining an ARB vehicle class from total length or from seating capacity was developed under this study based on the bus specification data for some 40 bus models. This methodology seems to work for the bus population in the future as well. However, bus technology is changing fairly rapidly particularly for alternative fuel buses. Therefore, some modification of the methodology may become necessary for such buses in the near future.

The driving patterns of transit and school buses have exhibited marked differences from those used in the FTP. Although the average trip speed is about the same around 15 mph for FTP and this study, the actual driving patterns determined by this study indicated more frequent and longer idling (~30% of total trip time in this study versus 20% in FTP) and a higher driving speed (21-25 mph vs 18 mph). The result implies that the real-world bus driving involves harder accelerations and more frequent stop-and-go driving than FTP, resulting in higher emission rates than those of the FTP-based emission factors. It is recommended that new test cycles for buses should be devised based on the driving pattern data of the present study and that a separate set of emission factors should be developed for buses in different weight classes or for transit buses and school busses.

APPENDIX A

Address List of Transit Bus Operators

ADDRESS LIST FOR FTA TRANSIT SYSTEMS

Transit System Name	Street Address	City	St	Zip
GOLDEN EMPIRE TRANSIT DISTRICT	1830 GOLDEN STATE AVENUE	BAKERSFIELD	CA	93301
SANTA CRUZ METROPOLITAN TRANSIT DISTRICT	920 PACIFIC AVE., SUITE 21	SANTA CRUZ	CA	95060
CITY OF MODESTO - INTRACITY TRANSIT	801 - 11TH STREET	MODESTO	CA	95354
SANTA MONICA MUNICIPAL BUS LINES	1660 SEVENTH STREET	SANTA MONICA	CA	90401
SAN MATEO COUNTY TRANSIT DISTRICT	1250 SAN CARLOS AVE., P.O. BOX 3006	SAN CARLOS	CA	94070
CITY OF TORRANCE TRANSIT SYSTEM	20500 MADRONA AVENUE	TORRANCE	CA	90503
STOCKTON METROPOLITAN TRANSIT DISTRICT	1533 EAST LINDSAY STREET	STOCKTON	CA	95205
SANTA CLARA COUNTY TRANSIT DISTRICT	1555 BERGER DRIVE, BLDG 2	SAN JOSE	CA	95112
ALAMEDA-CONTRA COSTA TRANSIT DISTRICT	1600 FRANKLIN STREET	OAKLAND	CA	94612
SAN FRANCISCO MUNICIPAL RAILWAY	949 PRESIDIO	SAN FRANCISCO	CA	94120
GOLDEN GATE BRIDGE, HIGHWAY AND TRANSPORTAT	P.O. BOX 9000, PRESIDIO STATION	SAN FRANCISCO	CA	94129
CITY OF SANTA ROSA	100 SANTA ROSA AVE., P.O. BOX 1678	SANTA ROSA	CA	95402
SACRAMENTO REGIONAL TRANSIT DISTRICT	1400 29TH STREET	SACRAMENTO	CA	95816
SANTA BARBARA METROPOLITAN TRANSIT DISTRICT	550 EAST COTA STREET	SANTA BARBARA	CA	93103
SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT	425 SOUTH MAIN STREET	LOS ANGELES	CA	90013
NORWALK TRANSIT SYSTEM	12700 NORWALK BLVD.	NORWALK	CA	90650
LONG BEACH PUBLIC TRANSPORTATION COMPANY	1300 GARDENIA AVE.	LONG BEACH	CA	90813
CITY OF LA MIRADA TRANSIT	13700 LA MIRADA BLVD	LA MIRADA	CA	90638
SAN DIEGO TRANSIT CORPORATION	100 16TH ST.	SAN DIEGO	CA	92101
FRESNO AREA EXPRESS	2223 "G" STREET	FRESNO	CA	93706
VALLEJO TRANSIT (BUS) VALLEJO-SAN FRANCISCO	555 SANTA CLARA STREET	VALLEJO	CA	94590
OMNITRANS	1700 WEST FIFTH STREET	SAN BERNADINO	CA	92411
NORTH SAN DIEGO COUNTY TRANSIT DEVELOPMENT	311 SOUTH TREMONT	OCEANSIDE	CA	92054
RIVERSIDE TRANSIT AGENCY	1825 THIRD STREET	RIVERSIDE	CA	92507
SOUTH COAST AREA TRANSIT	301 EAST THIRD STREET	OXNARD	CA	93030
ORANGE COUNTY TRANSIT DISTRICT	11222 ACACIA PARKWAY, P.O. BOX 3005	GARDEN GROVE	CA	92642
CULVER CITY MUNICIPAL BUS LINES	9815 W. JEFFERSON BLVD.	CULVER CITY	CA	90230
MONTEBELLO MUNICIPAL BUS LINES	311 SO. GREENWOOD	MONTEBELLO	CA	90640
CITY OF GARDENA MUNICIPAL BUS LINE	1700 W. 162 ST.	GARDENA	CA	90247
CITY OF COMMERCE MUNICIPAL BUSLINES	2535 COMMERCE WAY	COMMERCE	CA	90040
ARCADIA DIAL-A-RIDE	240 W. HUNTINGTON DRIVE	ARCADIA	CA	91007
SIMI VALLEY TRANSIT	2929 TAPO CANYON ROAD	SIMI VALLEY	CA	93063
CITY OF CORONA DIAL-A-RIDE	815 WEST SIXTH STREET	CORONA	CA	91720
MONTEREY COUNTY RIDES	312 EAST ALISAL STREET	SALINAS	CA	93901
HUB AREA TRANSIT AUTHORITY	1612 POOLE BOULEVARD	YUBA CITY	CA	95993
MONTEREY-SALINAS TRANSIT	ONE RYAN RANCH ROAD	MONTEREY	CA	93940
LOS ANGELES COUNTY TRANSPORTATION	818 WEST 7TH STREET, SUITE 1100	LOS ANGELES	CA	90017
CENTRAL CONTRA COSTA TRANSIT AUTHORITY	2477 ARNOLD INDUSTRIAL WAY	CONCORD	CA	94598
SUNLINE TRANSIT AGENCY	32-505 HARRY OLIVER TRAIL, P.O. BOX 398	THOUSAND PALMS	CA	92276
CITY OF RIVERSIDE SPECIAL TRANSPORTATION	8095 LINCOLN AVENUE	RIVERSIDE	CA	92504
SANTA MARIA AREA TRANSIT	110 EAST COOK STREET	SANTA MARIA	CA	93454
THE V.I.N.E. CITY OF NAPA	P.O BOX 660	NAPA	CA	94559
SONOMA COUNTY TRANSIT	355 WEST ROBLES AVENUE	SANTA ROSA	CA	95407
YOLO COUNTY TRANSIT AUTHORITY	825 EAST ST., SUITE 120	WOODLAND	CA	95695
CITY OF VISALIA-VISALIA CITY COACH	707 W ACEQUIA AV	VISALIA	CA	93291
CITY OF FAIRFIELD, FAIRFIELD TRANSIT SYSTEM	1000 WEBSTER STREET	FAIRFIELD	CA	94533
REDDING AREA BUS AUTHORITY	760 PARKVIEW AVE	REDDING	CA	96001
LAGUNA BEACH MUNICIPAL TRANSIT LINES	505 FOREST AVENUE	LAGUNA BEACH	CA	92651
CHICO AREA TRANSIT SYSTEM, CITY OF CHICO	2725 A. HIGHWAY 32 WEST	CHICO	CA	95926
CITY OF MERCED TRANSIT SYSTEM	1776 GROGAN AVENUE	MERCED	CA	95340

APPENDIX B

School Bus Survey Questionnaires

VALLEY RESEARCH CORPORATION

15904 STRATHERN STREET, SUITE 26, VAN NUYS, CALIFORNIA 91406 (818) 902-0022 • FAX: (818) 902-1367

October 28, 1992

TO: FIRST LAST
TITLE
ORGANIZATION
ADDRESS
CITY, CA ZIP

FROM: Craig Tranby
Survey Coordinator
Valley Research Corporation

Ron Kinney
California Dept. of Education
School Transportation

RE: Request for School Bus Data

The California Air Resources Board (ARB) has contracted with Valley Research Corporation (VRC) to study school bus activity in the State of California. This information is essential for improving the inventory of air pollution emissions from school buses. A comprehensive, accurate, and current inventory of emissions is needed to help fulfill ARB's mandate to improve air quality throughout the state. To gather basic data on school bus fleet composition and activity, VRC is contacting every school bus fleet operator in the state and asking them to provide information on a 3-page questionnaire which is enclosed in this packet.

California operates over 22,500 school buses. The information that you provide will in all probability have a profound effect on the future of school transportation in California. This information will be vital when justifying the need to acquire or replace school buses to reduce grid lock and improve air quality. The data will be used to develop statistical estimates of school bus activity on a county by county basis. The enclosed letter from the Air Resources Board further explains the rationale for this request.

The questionnaire requests 1991 data for active school buses in your fleet during that calendar year. An active school bus is defined as a van-sized or larger vehicle transporting school children at least once during 1991 which we are using as a base year. If for some reason 1991 data are not available, please provide data for the most recent year available and clearly indicate that year. If your fleet has some or all of its buses owned or operated by a contractor, please answer the questions yourself, or in cooperation with the contractor, as much as possible. If you are unable to complete the questionnaire but the contractor would, please complete Page 1 of the questionnaire and provide the contractor's complete name, address, and phone number. If you have no busing, again please complete Page 1 of the questionnaire and return it to VRC as soon as possible.

Please complete the enclosed forms, make a copy for your records, and return them to VRC by November 20, 1992. Should you have any questions, please call VRC at (818) 902-0022 or fax questions to (818) 902-1367. Thank You.

STATE OF CALIFORNIA
AIR RESOURCES BOARD
2020 L STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

PETE WILSON, Governor

(916) 445-0753
(916) 322-4357 (FAX)

October 20, 1992

Dear Sir/Madam:

This letter is to confirm that Valley Research Corporation (VRC) is under contract to the California Air Resources Board (ARB) to study school bus emissions-related activity in the State of California. The project is entitled, "On-Road Motor Vehicle Activity Data", and is being performed under ARB Contract Number A132-182.

As part of its study, VRC is conducting a survey of all school bus fleet operators in the state. The objective of the study is to upgrade the database used to calculate the ARB's on-road motor vehicle emission inventories. Your cooperation in completing the enclosed questionnaire will be greatly appreciated.

Please be advised that Section 39607 of the California Health and Safety Code (HSC) requires ARB to inventory sources of air pollution to determine the kinds and amount of such pollutants. HSC Sections 39600 and 41511 authorize the ARB to do such acts as may be necessary to carry out its responsibilities, including the adoption of rules and regulations to require the operator of any air pollution source to take such action as the board determines reasonable for the determination of the amount of emissions from the source. The ARB has adopted a regulation of Section 91100 of Title 17 of the California Code of Regulations (CCR) permitting the ARB or its authorized representative to require the owner or operator of a source which may cause the issuance of air contaminants to provide information necessary to determine the nature and quantity of such emissions. VRC has been awarded a contract to perform air pollution research for the ARB pursuant to HSC Section 39703(d) and is an authorized representative of the ARB within the meaning of ARB regulations. Please consider this a formal request for information pursuant to the authority cited above.

Should you have any questions regarding the objectives of this research, please call Dr. Robert Grant of ARB at (916) 323-5774. Questions of a technical nature can be referred to Mr. Craig Tranby or Mr. Steve Sidawi of VRC at (818) 902-0022.

Again, thank you for your cooperation.

Sincerely yours,

John R. Holmes, Ph.D.
Chief, Research Division

Enclosures

ARB SCHOOL BUS SURVEY

Please complete and mail or fax to:

Mr. Craig Tranby
Survey Coordinator
Valley Research Corporation
15904 Strathern St., Suite 26
Van Nuys, CA 91406-1362

TEL: (818) 902-0022
FAX: (818) 902-1367

If either of the following conditions is true, you are "exempt" from this survey. Please place your initials by the condition and complete this page only.

- This organization does not have any bus service ____
- This organization uses another organization (i.e., contractor) to provide busing services and does not have access to the requested information (Please indicate that organization's name, address, & phone number on the back of this sheet.) ____

All other operators must answer items 1 through 7 below and complete Form A.

1. Exact name and address of the organization for which you are providing information (if different from label).

   Organization Name: _____

   Street Address: _____

   City, State, Zip: _____

2. **Your Name:** _____

   Your Title: _____

   Phone No.: _____ **Fax No.:** _____

3. Please supply or estimate the percentages of annual miles traveled by buses in the fleet by the following types of activity:

Home to School Miles	_____
Deadhead Miles	_____
Activity Trip Miles	_____
Operator Training Miles	_____

Sum of percentages must equal 100%

4. Please supply or estimate the percentages of annual miles traveled by buses in the fleet by the following types of roads:

Urban Surface Streets	_____
Urban Freeways	_____
Intercity Highways	_____
Rural Roads	_____

Sum of percentages must equal 100%

5. Please supply or estimate the percentages of annual miles traveled by buses in the fleet by the following days of the week:

Monday through Friday	_____
Saturday & Sunday	_____

Sum of percentages must equal 100%

6. Please supply the total miles traveled by all buses in the fleet during calendar year 1991:

_____ miles

7. Using 1991 as a base year, please supply or estimate the percentages of total miles traveled by buses in the fleet in each of the years 1987 to 1990 relative to 1991. Then supply the projected percentages of the years 1992 and 1993 relative to 1991.

1987	_____
1988	_____
1989	_____
1990	_____
1991	100%
1992 (projected)	_____
1993 (projected)	_____

FORM A: INVENTORY OF SCHOOL BUSES

(see back of page for instructions)

A	B	C	D	E	F	G	H	I	J	K	L	M
	GENERAL DATA					ENGINE/FUEL DATA						
Bus Type	Operator Code	Manufacturer Code	Model	Year of Manufacture	Length (ft)	Engine Type	Fuel Type Code	Fuel Economy (mi/gal)	Number of Buses in Fleet Active/Inactive	Avg. Lifetime Mileage for Active Buses	Avg. Miles Traveled in 1991	Engine Rebuild Code
1									/			
2									/			
3									/			
4									/			
5									/			
6									/			
7									/			
8									/			
9									/			
10									/			
11									/			
12									/			

Column	Instructions
A	Form A is intended to compile a complete inventory for all active buses in your fleet. The form is "bus type" based, that is, each of the pre-numbered lines on the form (in column A) will represent a unique bus type within your fleet as determined by manufacturer, model, and year built (columns C, D, & E). If your fleet contains more than the 12 bus types allotted, please copy Form A while still blank and re-number from 13 to as many types as necessary.
B	Indicate the operator type using the following designations: **D1** - Owned and operated by school district, **D2** - Owned by school district and operated by contractor, **C1** - Owned and operated by contractor, **C2** - Owned by contractor (or other outside organization) and operated by school district.
C	Indicate the manufacturer using the following designations: **B** - Bluebird, **Ca** - Carpenter, **Co** - Collins, **Cr** - Crown, **Gl** - Gillig, **Gm** - GMC, **Gr** - Girardin, **M** - Mid, **St** - STURiCORP, **Su** - Superior, **T** - Thomas Built, **V** - Van Con, **Wd** - Ward, **Wy** - Wayne. For a manufacturer not listed, please indicate the manufacturer name.
D	Indicate whether *conventional* (**C**) or *transit* (**T**) style bus followed by the commonly-used model name or number given by the manufacturer (e.g., Orion II, Lifeguard, etc.).
E	Indicate year of original manufacture (not rebuild or other modification).
F	Indicate the bus length as designated by the manufacturer.
G	Indicate engine type by manufacturer (e.g., DD = Detroit Diesel, CU = Cummins, CP = Caterpillar, IN = International/Navistar, GM = General Motors, FO = Ford, DO = Dodge, HE = Hercules, TE = Tecogen, etc.) and model number.
H	Indicate primary fuel type using the following fuel type codes: **B** - battery electric, **D#X** - number X diesel fuel, **E** - ethanol, **G** - gasoline, **K** - kerosene, **M** - methanol, **N** - natural gas, **P** - propane.
I	Indicate fuel economy in miles per gallon or miles per standard cubic foot (if CNG).
J	Indicate the number of active (used during 1991 or year of record) and inactive (not used during 1991 or year of record) buses of the designated "bus type".
K	Indicate the average current lifetime mileage for <u>active</u> buses for the designated bus type.
L	Indicate the average miles travelled in 1991, or year of record, for each bus type (by definition inactive buses are not included).
M	Indicate the typical range of miles travelled before an engine rebuild is required for each bus type using the following codes: **A** = 100,000 or less, **B** = 100,001-150,000, **C** = 150,001-200,000, **D** = 200,001-250,000, **E** = 250,001-300,000, **F** = Over 300,000.

A few weeks ago a questionnaire was mailed to this address seeking information about your school bus fleet. As of this date, we have yet to receive a response from your organization.

I am writing again because of the importance of your responses to the study being conducted for the California Air Resources Board (ARB) in Sacramento. May I remind you that this request for information is a formal one made pursuant to ARB's responsibilities mandated by the provisions of existing California law.

Please complete and return your questionnaire by fax, (818) 902-1367, or mail by December 16. If by some chance you did not receive the questionnaire, or it was misplaced, please call me right now at (818) 902-0022, and I will get another one in the mail to you. If you are having difficulty completing the questionnaire for the calendar year 1991, I remind you that you may use another year (including fiscal year) so long as you note it on the questionnaire. Please call if you have any other questions or concerns.

Sincerely,
VALLEY RESEARCH CORPORATION

Craig Tranby

Craig Tranby, Survey Coordinator

Valley Research Corporation
15904 Strathern Street, Suite 26
Van Nuys, California 91406

DO NOT FORWARD: ADDRESS CORRECTION REQUESTED

VALLEY RESEARCH CORPORATION

15904 STRATHERN STREET, SUITE 26, VAN NUYS, CALIFORNIA 91406 (818) 902-0022 • FAX. (818) 902 1367

January 6, 1993

TO: FIRST LAST
TITLE
ORGANIZATION
ADDRESS
ADDRESS2
CITY, STATE ZIP

FROM: Craig Tranby
Survey Coordinator
Valley Research Corporation

Ron Kinney
California Dept. of Education
School Transportation

RE: Request for School Bus Data

The California Air Resources Board (ARB) has contracted with Valley Research Corporation (VRC) to study school bus activity in the State of California. This information is essential for improving the inventory of air pollution emissions from school buses. A comprehensive, accurate, and current inventory of emissions is needed to help fulfill ARB's mandate to improve air quality throughout the state. To gather basic data on school bus fleet composition and activity, VRC is contacting every school bus fleet operator in the state and asking them to provide information on a 3-page questionnaire which is enclosed in this packet.

California operates over 22,500 school buses. The information that you provide will in all probability have a profound effect on the future of school transportation in California. This information will be vital when justifying the need to acquire or replace school buses to reduce grid lock and improve air quality. The data will be used to develop statistical estimates of school bus activity on a county by county basis. The enclosed letter from the Air Resources Board further explains the rationale for this request.

VRC has just completed a survey to some 900 school districts throughout California. While that survey provided much information on school district-owned buses, little was provided for contractor-owned school buses. We have, therefore, decided to distribute a survey directly to the school bus contractor principal offices for California. Unlike the district by district survey which requested specific data on local school bus fleets, this survey requests general information about the contractor's statewide fleet of active school buses (please do not include non-school bus vehicles, i.e., charter buses, in your response). An "active school bus" is defined as a bus transporting school children at least once during 1991 which we are using as a base year. If for some reason 1991 data are not available, please provide data for the most recent year available and clearly indicate that year.

Please complete the enclosed forms, make a copy for your records, and return them to VRC by January 29, 1993. Should you have any questions, please call VRC at (818) 902-0022. Thank You.

ARB SCHOOL BUS SURVEY

Please complete and mail or fax to:

Mr. Craig Tranby
Survey Coordinator
Valley Research Corporation
15904 Strathern St., Suite 26
Van Nuys, CA 91406-1362

TEL: (818) 902-0022
FAX: (818) 902-1367

Please answer items 1 through 7 below and complete Form A for your California school bus fleet. Do not include non-school buses or their activities in your responses.

1. Exact name and address of the organization for which you are providing information (if different from label).

   Organization Name: _____

   Street Address: _____

   City, State, Zip: _____

2. **Your Name:** _____

   Your Title: _____

   Phone No.: _____ **Fax No.:** _____

   Year Start Date: ____/____/____ **Year End Date:** ____/____/____
   (Fill in this item to indicate the one year time period that your responses represent, particularly if you are using the fiscal year or a non-1991 year.)

3. Please supply or estimate the percentages of annual miles traveled by buses in the fleet by the following types of activity:

Home to School Miles	_____
Deadhead Miles	_____
Activity Trip Miles	_____
Operator Training Miles	_____

Sum of percentages must equal 100%

4. Please supply or estimate the percentages of annual miles traveled by buses in the fleet by the following types of roads:

Urban Surface Streets	_____
Urban Freeways	_____
Intercity Highways	_____
Rural Roads	_____

Sum of percentages must equal 100%

5. Please supply or estimate the percentages of annual miles traveled by buses in the fleet by the following days of the week:

Monday through Friday	_____
Saturday & Sunday	_____

Sum of percentages must equal 100%

6. Please supply the total miles traveled by all buses in the fleet during fiscal year 1991:

_____ miles

7. Using 1991 as a base year, please supply or estimate the percentages of total miles traveled by buses in the fleet in each of the years 1987 to 1990 relative to 1991. Then supply the projected percentages of the years 1992 and 1993 relative to 1991.

1987	_____
1988	_____
1989	_____
1990	_____
1991	100%
1992 (projected)	_____
1993 (projected)	_____

FORM A: CONTRACTOR SCHOOL BUS INVENTORY FOR CALIFORNIA
(see back of page for instructions)

A	B	C	D	E	F
Year of Manufacture	Bus Size Class (circle one per line)	Fuel Type Code	Number of Active Buses	AAAM for 1991	Rebuild Code
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Type II				
	Type I Tyw II				
	Type I Type II				
	Type I Type II				
	Type I Type II				

FORM A: INSTRUCTIONS

Form A is intended to compile a complete inventory for all active buses in your statewide fleet. The form is "bus type" based, that is, each line will represent a unique bus type within your fleet as determined by year built, bus size class, and fuel type (columns A, B, & C). If your fleet contains more than the 18 bus types allotted, please copy Form A while still blank and re-number from 19 to as many types as necessary.

Column	Instructions
A	Indicate year of original manufacture (not rebuild or other modification).
B	Indicate bus size class according to California Vehicle Code conventions, Type I (>16 passenger design) or Type II. If both size classes exist in your fleet for the same year of manufacture or the same fuel type, please fill in a separate line for each type.
C	Indicate primary fuel type using the following fuel type codes: **B** - battery electric, **D#X** - number X diesel fuel (e.g., for No. 2 diesel fuel indicate *D#2*), **E** - ethanol, **G** - gasoline, **K** - kerosene, **M** - methanol, **N** - natural gas, **P** - propane.
D	Indicate the number of active (used during 1991 or year of record) buses described by columns A, B, & C.
E	Indicate the average annual accumulated miles (AAAM) per bus in 1991, or year of record, for the buses described by columns A, B, & C.
F	Indicate the typical range of miles traveled before an engine rebuild occurred (leave blank if rebuilds have typically not occurred yet) using the following codes: **A** = 100,000 miles or less, **B** = 100,001-150,000, **C** = 150,001-200,000, **D** = 200,001-250,000, **E** = 250,001-300,000, **F** = Over 300,000.

APPENDIX C

1990 Census Statistics on
California Student Enrollment

1990 CENSUS STATISTICS ON CALIFORNIA STUDENT ENROLLMENT

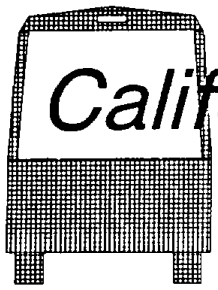
County	Students	% Students Private Sch	CHP Divison
Alameda	196921	11.3	3
Alpine	195	4.1	2
Amador	4547	5.2	2
Butte	27899	5.5	2
Calaveras	5508	4.7	2
Colusa	3689	3.7	1
Contra Costa	131788	9.9	3
Del Norte	4193	6.9	1
El Dorado	22395	3.6	2
Fresno	141261	3.6	4
Glenn	5157	5.4	1
Humboldt	20564	5.5	1
Imperial	27796	3.5	6
Inyo	2997	1.5	8
Kern	93883	4.8	4
Kern	17391	5.2	8
Kings	21114	5.7	4
Lake	8305	4.7	1
Lassen	4883	4.6	1
Los Angeles	1565758	11.6	5
Los Angeles	50146	9.4	8
Madera	19252	3.6	4
Marin	28120	19.9	3
Mariposa	2154	4.0	4
Mendocino	15280	6.3	1
Merced	41371	4.7	4
Modoc	1843	3.0	1
Mono	1502	4.3	2
Monterey	63863	6.1	7
Napa	17305	10.8	3
Nevada	12980	5.1	2
Orange	392695	9.5	6
Placer	29850	7.6	2
Plumas	3557	2.4	1
Riverside	94926	7.2	8
Riverside	121867	5.8	6
Sacramento	177997	8.9	2
San Benito	7872	7.6	7
San Bernardino	279558	7.3	8
San Bernardino	5725	9.9	6
San Diego	397787	7.6	6
San Francisco	83931	22.5	3
San Joaquin	95423	6.5	4
San Luis Obispo	31896	8.5	7
San Mateo	93061	16.3	3
Santa Barbara	56308	8.9	7
Santa Clara	237043	9.9	3
Santa Cruz	36017	7.9	7
Shasta	27192	7.9	1
Sierra	469	.6	2
Siskiyou	8011	2.7	1
Solano	62997	7.3	3
Sonoma	61391	8.0	3
Stanislaus	74366	5.4	4
Sutter	12729	5.3	2

1990 CENSUS STATISTICS ON CALIFORNIA STUDENT ENROLLMENT

County	Students	% Students Private Sch	CHP Divison
Tehama	9419	2.9	1
Trinity	2535	5.2	1
Tulare	71177	3.6	4
Tuolumne	7721	7.3	4
Ventura	122565	9.7	7
Yolo	21721	8.4	2
Yuba	11800	2.8	2
Total:	5199666		

APPENDIX D

Chase Car Survey Handout, Letters
and Log Sheet



California Bus Activity Study

General Information

What is the purpose of the study?

The purpose of this study is to record details of bus driving patterns such as speed distribution, acceleration/deceleration events, and duration and frequency of idling. Instrumented study cars are being used to follow selected buses under normal operation. The study is **not** designed to monitor either smoke or any other emissions. The information obtained will be used in conjunction with general information on bus fleets to make estimates of the air pollution emission inventory for buses.

Note to bus drivers:
During the route we ask you only to drive normally, as if the study car were not present. This is to ensure that we experience actual real-world driving conditions. The driver of the study car will be happy to answer any questions before the start of the route. Your management has already been notified as to the nature of the study.

How were the bus routes selected?

Routes were selected using a scientific random sampling technique, designed to give a representative mix of various types of transit and school bus service. More than 200 bus routes will be included.

Who is conducting the study?

The study is being conducted by the Valley Research Corporation (VRC) under contract to the Air Resources Board (ARB). The driver of the instrumented study car is a safe and experienced VRC staff researcher. Further inquiries may be directed to:

Yuji Horie, Ph.D.
Principal Investigator
Valley Research Corporation
15904 Strathern Street, Suite 26
Van Nuys, California 91406

Robert Grant, Ph.D.
Contract Manager
California Air Resources Board
Research Division
2020 L Street
Sacramento, California 95814

Sections 39600 and 41511 of the California Health and Safety Code authorize the Air Resources Board to take actions as it sees necessary to inventory sources of air pollutants. VRC is an authorized representative of the ARB within the meaning of ARB regulations.

STATE OF CALIFORNIA
AIR RESOURCES BOARD
2020 L STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

PETE WILSON, Governor

March 18, 1993

Arthur T. Leahy
Assistant General Manager-Operations
Southern California Rapid Transit District
425 S. Main Street
Los Angeles, CA 90013

Attn: Operations Manager

Dear Mr. Leahy:

Section 39607 of the California Health and Safety Code (HSC) requires ARB to inventory sources of air pollution to determine the kinds and amount of such pollutants. HSC Sections 39600 and 41511 authorize the ARB to take such action as the Board determines reasonable for the determination of the amount of emissions from the source. Valley Research Corporation (VRC) has been awarded a contract to compile bus operations data for the ARB. VRC is an authorized representative of the ARB within the meaning of ARB regulations.

Under the contract entitled "On-Road Motor Vehicle Activity Datam" (ARB Contract No. A132-182), VRC has been conducting a study on driving patterns of transit buses in Southern California by following randomly-selected transit buses for about 30 minutes at a time in an automobile fitted to record speed, acceleration, and idling data. No emission observations or measurements are being made. The driver of the VRC automobile has attempted to notify the bus driver immediately prior to following each bus. However, in certain cases notification of the bus driver was not possible, such as when a route originated from a "transit vehicle only" area. Therefore, VRC needs your help in notifying all appropriate transit personnel, including security officers, along the selected bus routes.

Attached is a table indicating the selected bus routes, the projected dates and the numbers of study events. VRC will notify you as to any changes in this schedule. If you have any questions regarding the objectives of this research, please call me at (916) 323-5774. If you have specific questions regarding scheduling, please contact Craig Tranby of VRC at (818) 902-0022.

Again, thank you for your cooperation.

Sincerely yours,

Robert Grant, Ph.D.
Research Contract Manager

Enclosure

File Name: _____

CHASE CAR STUDY TRIP LOG

Type	Route	Date	St Time	Start Location	Operator	Bus Description	# S Stops	End Time	End Location	Dist. (mi.)

APPENDIX E

Distributions of Driving Time and VMT by Speed Range

TIME AND VMT FRACTIONS FOR THE FTP CYCLE

TRIP TYPE: FTP

TRIP DIST: 7.5 mi.
TRIP DUR: .52 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction	Norm. VMT Fraction
ISHORT	0.0	.02	0.00	0.00
IMEDIUM	0.0	.18	0.00	0.00
ILONG	0.0	0.00	0.00	0.00
0-4 MPH	2.5	.05	.01	.01
5-9 MPH	7.5	.05	.03	.02
10-14 MPH	12.5	.05	.04	.03
15-19 MPH	17.5	.09	.11	.07
20-24 MPH	22.5	.15	.24	.16
25-29 MPH	27.5	.18	.33	.23
30-34 MPH	32.5	.08	.17	.12
35-39 MPH	37.5	.05	.13	.09
40-44 MPH	42.5	.01	.02	.01
45-49 MPH	47.5	.03	.09	.06
50-54 MPH	52.5	.05	.20	.13
>=55 MPH	60.0	.03	.11	.08
TOTAL:		1.00	1.48	1.00

TIME AND VMT FRACTIONS FOR CHASE TYPES - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - URBAN:WKDY-PK - 30 TRIPS

TRIP DIST: 7.0 mi.
TRIP DUR: .49 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.04	0.00
IMEDIUM	0.0	.20	0.00
ILONG	0.0	.07	0.00
0-4 MPH	2.5	.05	.01
5-9 MPH	7.5	.08	.04
10-14 MPH	12.5	.09	.08
15-19 MPH	17.5	.09	.11
20-24 MPH	22.5	.10	.17
25-29 MPH	27.5	.11	.20
30-34 MPH	32.5	.08	.18
35-39 MPH	37.5	.04	.11
40-44 MPH	42.5	.02	.05
45-49 MPH	47.5	.01	.03
50-54 MPH	52.5	.00	.01
>=55 MPH	60.0	.00	.01
TOTAL:		1.00	1.01

TRIP TYPE: TRANSIT - URBAN:WKDY-OFF - 30 TRIPS

TRIP DIST: 7.6 mi.
TRIP DUR: .49 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.04	0.00
IMEDIUM	0.0	.20	0.00
ILONG	0.0	.06	0.00
0-4 MPH	2.5	.05	.01
5-9 MPH	7.5	.08	.04
10-14 MPH	12.5	.09	.08
15-19 MPH	17.5	.09	.10
20-24 MPH	22.5	.10	.14
25-29 MPH	27.5	.10	.19
30-34 MPH	32.5	.08	.17
35-39 MPH	37.5	.05	.13
40-44 MPH	42.5	.02	.06
45-49 MPH	47.5	.01	.03
50-54 MPH	52.5	.00	.01
>=55 MPH	60.0	.01	.05
TOTAL:		1.00	1.01

TIME AND VMT FRACTIONS FOR CHASE TYPES - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - URBAN:SAT - 12 TRIPS

TRIP DIST: 7.8 mi.
TRIP DUR: .50 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.04	0.00
IMEDIUM	0.0	.17	0.00
ILONG	0.0	.10	0.00
0-4 MPH	2.5	.05	.01
5-9 MPH	7.5	.07	.03
10-14 MPH	12.5	.09	.07
15-19 MPH	17.5	.11	.12
20-24 MPH	22.5	.11	.16
25-29 MPH	27.5	.10	.18
30-34 MPH	32.5	.08	.17
35-39 MPH	37.5	.05	.12
40-44 MPH	42.5	.02	.06
45-49 MPH	47.5	.01	.02
50-54 MPH	52.5	.00	.02
>=55 MPH	60.0	.01	.05
TOTAL:		1.00	1.00

TRIP TYPE: TRANSIT - URBAN:SUN - 12 TRIPS

TRIP DIST: 8.2 mi.
TRIP DUR: .50 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.03	0.00
IMEDIUM	0.0	.17	0.00
ILONG	0.0	.11	0.00
0-4 MPH	2.5	.04	.01
5-9 MPH	7.5	.06	.03
10-14 MPH	12.5	.08	.06
15-19 MPH	17.5	.09	.10
20-24 MPH	22.5	.11	.16
25-29 MPH	27.5	.10	.17
30-34 MPH	32.5	.09	.18
35-39 MPH	37.5	.06	.13
40-44 MPH	42.5	.03	.07
45-49 MPH	47.5	.01	.03
50-54 MPH	52.5	.01	.02
>=55 MPH	60.0	.02	.06
TOTAL:		1.00	1.00

TIME AND VMT FRACTIONS FOR CHASE TYPES - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - SMALL URB:WKDY-PK - 20 TRIPS

TRIP DIST: 8.9 mi.
TRIP DUR: .52 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.03	0.00
IMEDIUM	0.0	.14	0.00
ILONG	0.0	.14	0.00
0-4 MPH	2.5	.05	.01
5-9 MPH	7.5	.07	.03
10-14 MPH	12.5	.07	.05
15-19 MPH	17.5	.07	.07
20-24 MPH	22.5	.07	.10
25-29 MPH	27.5	.09	.15
30-34 MPH	32.5	.10	.19
35-39 MPH	37.5	.08	.17
40-44 MPH	42.5	.05	.12
45-49 MPH	47.5	.03	.07
50-54 MPH	52.5	.01	.03
>=55 MPH	60.0	.00	.02
TOTAL:		1.00	1.00

TRIP TYPE: TRANSIT - SMALL URB:WKDY-OFF - 20 TRIPS

TRIP DIST: 9.4 mi.
TRIP DUR: .53 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.03	0.00
IMEDIUM	0.0	.13	0.00
ILONG	0.0	.15	0.00
0-4 MPH	2.5	.04	.01
5-9 MPH	7.5	.07	.03
10-14 MPH	12.5	.07	.05
15-19 MPH	17.5	.08	.08
20-24 MPH	22.5	.08	.10
25-29 MPH	27.5	.09	.14
30-34 MPH	32.5	.10	.18
35-39 MPH	37.5	.08	.18
40-44 MPH	42.5	.06	.13
45-49 MPH	47.5	.02	.07
50-54 MPH	52.5	.01	.04
>=55 MPH	60.0	.00	.01
TOTAL:		1.00	1.00

TIME AND VMT FRACTIONS FOR CHASE TYPES - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - SMALL URB:WKEND - 16 TRIPS

TRIP DIST: 8.0 mi.
TRIP DUR: .50 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.02	0.00
IMEDIUM	0.0	.12	0.00
ILONG	0.0	.18	0.00
0-4 MPH	2.5	.04	.01
5-9 MPH	7.5	.07	.03
10-14 MPH	12.5	.08	.06
15-19 MPH	17.5	.07	.08
20-24 MPH	22.5	.08	.12
25-29 MPH	27.5	.10	.17
30-34 MPH	32.5	.09	.19
35-39 MPH	37.5	.07	.15
40-44 MPH	42.5	.04	.10
45-49 MPH	47.5	.02	.05
50-54 MPH	52.5	.01	.03
>=55 MPH	60.0	.00	.01
TOTAL:		1.00	1.00

TRIP TYPE: SCHOOL - URBAN:AM - 14 TRIPS

TRIP DIST: 8.2 mi.
TRIP DUR: .49 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.02	0.00
IMEDIUM	0.0	.14	0.00
ILONG	0.0	.14	0.00
0-4 MPH	2.5	.04	.01
5-9 MPH	7.5	.07	.03
10-14 MPH	12.5	.08	.06
15-19 MPH	17.5	.08	.08
20-24 MPH	22.5	.09	.13
25-29 MPH	27.5	.10	.16
30-34 MPH	32.5	.09	.19
35-39 MPH	37.5	.06	.14
40-44 MPH	42.5	.03	.07
45-49 MPH	47.5	.01	.03
50-54 MPH	52.5	.03	.08
>=55 MPH	60.0	.01	.04
TOTAL:		1.00	1.01

TIME AND VMT FRACTIONS FOR CHASE TYPES - 210 TRIPS TOTAL

TRIP TYPE: SCHOOL - URBAN:PM - 14 TRIPS

TRIP DIST: 7.8 mi.
TRIP DUR: .46 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.03	0.00
IMEDIUM	0.0	.13	0.00
ILONG	0.0	.15	0.00
0-4 MPH	2.5	.04	.01
5-9 MPH	7.5	.08	.03
10-14 MPH	12.5	.08	.06
15-19 MPH	17.5	.08	.08
20-24 MPH	22.5	.09	.12
25-29 MPH	27.5	.10	.15
30-34 MPH	32.5	.08	.16
35-39 MPH	37.5	.06	.13
40-44 MPH	42.5	.02	.04
45-49 MPH	47.5	.01	.02
50-54 MPH	52.5	.02	.06
>=55 MPH	60.0	.04	.15
TOTAL:		1.00	1.01

TRIP TYPE: SCHOOL - SMALL URB:AM - 14 TRIPS

TRIP DIST: 7.3 mi.
TRIP DUR: .43 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.02	0.00
IMEDIUM	0.0	.15	0.00
ILONG	0.0	.14	0.00
0-4 MPH	2.5	.05	.01
5-9 MPH	7.5	.08	.03
10-14 MPH	12.5	.09	.06
15-19 MPH	17.5	.07	.08
20-24 MPH	22.5	.08	.11
25-29 MPH	27.5	.09	.14
30-34 MPH	32.5	.08	.15
35-39 MPH	37.5	.06	.14
40-44 MPH	42.5	.05	.12
45-49 MPH	47.5	.02	.06
50-54 MPH	52.5	.03	.09
>=55 MPH	60.0	.00	.01
TOTAL:		1.00	1.01

TIME AND VMT FRACTIONS FOR CHASE TYPES - 210 TRIPS TOTAL

TRIP TYPE: SCHOOL - SMALL URB:PM - 14 TRIPS

TRIP DIST: 7.6 mi.
TRIP DUR: .43 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.02	0.00
IMEDIUM	0.0	.12	0.00
ILONG	0.0	.17	0.00
0-4 MPH	2.5	.05	.01
5-9 MPH	7.5	.07	.03
10-14 MPH	12.5	.08	.06
15-19 MPH	17.5	.08	.08
20-24 MPH	22.5	.08	.10
25-29 MPH	27.5	.08	.12
30-34 MPH	32.5	.07	.13
35-39 MPH	37.5	.05	.11
40-44 MPH	42.5	.04	.09
45-49 MPH	47.5	.04	.10
50-54 MPH	52.5	.03	.08
>=55 MPH	60.0	.03	.09
TOTAL:		1.00	1.01

TRIP TYPE: SCHOOL - RURAL:AM - 7 TRIPS

TRIP DIST: 11.7 mi.
TRIP DUR: .42 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.01	0.00
IMEDIUM	0.0	.11	0.00
ILONG	0.0	.06	0.00
0-4 MPH	2.5	.03	.00
5-9 MPH	7.5	.06	.02
10-14 MPH	12.5	.05	.02
15-19 MPH	17.5	.05	.03
20-24 MPH	22.5	.06	.05
25-29 MPH	27.5	.08	.08
30-34 MPH	32.5	.07	.08
35-39 MPH	37.5	.08	.11
40-44 MPH	42.5	.09	.13
45-49 MPH	47.5	.09	.15
50-54 MPH	52.5	.10	.19
>=55 MPH	60.0	.07	.15
TOTAL:		1.00	1.01

TIME AND VMT FRACTIONS FOR CHASE TYPES - 210 TRIPS TOTAL

TRIP TYPE: SCHOOL - RURAL:PM - 7 TRIPS

TRIP DIST: 10.4 mi.
TRIP DUR: .47 hr.

SPEED/IDLE	Vsi	Time Fraction	VMT Fraction
ISHORT	0.0	.02	0.00
IMEDIUM	0.0	.13	0.00
ILONG	0.0	.07	0.00
0-4 MPH	2.5	.03	.00
5-9 MPH	7.5	.07	.02
10-14 MPH	12.5	.06	.04
15-19 MPH	17.5	.07	.05
20-24 MPH	22.5	.09	.09
25-29 MPH	27.5	.09	.11
30-34 MPH	32.5	.09	.13
35-39 MPH	37.5	.07	.11
40-44 MPH	42.5	.08	.15
45-49 MPH	47.5	.06	.12
50-54 MPH	52.5	.05	.12
>=55 MPH	60.0	.02	.07
TOTAL:		1.00	1.01

APPENDIX F

Summary Statistics of FTP Cycle and Actual Bus Driving Pattern Data

SUMMARY OF FTP DATA

TRIP TYPE: FTP

TRIP DIST:	7.5 mi.	HARD ACCEL FRCT:	.09
TRIP DUR:	31.2 min.	CRUISING FRCT:	.63
SERVICE STOPS:		HARD DECEL FRCT:	.09
TRIP SPEED:	14.4 mph	IDLE FRCT:	.19
DRIVING SPEED:	17.9 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	8.0	.018					
IMEDIUM	14.0	.176					
ILONG	0.0	0.000					
0-4 MPH			.015	.007	.004	.008	.011
5-9 MPH			.018	.006	.002	.003	.020
10-14 MPH			.018	.005	.003	.007	.018
15-19 MPH			.020	.018	.009	.026	.018
20-24 MPH			.012	.039	.036	.055	.011
25-29 MPH			.007	.042	.060	.062	.004
30-34 MPH			.001	.019	.025	.028	.003
35-39 MPH			0.000	.009	.029	.010	.002
40-44 MPH			0.000	.004	0.000	.003	0.000
45-49 MPH			0.000	.005	.014	.009	0.000
50-54 MPH			0.000	.018	.018	.018	0.000
>=55 MPH			0.000	.004	.016	.006	0.000
TOTAL:	22.0	.194	.091	.177	.215	.235	.088

SUMMARY OF CHASE CAR DATA - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - URBAN:WKDY-PK - 30 TRIPS

TRIP DIST: 7.0 mi.
TRIP DUR: 29.3 min.
SERVICE STOPS: 15.9
TRIP SPEED: 14.3 mph
DRIVING SPEED: 20.7 mph

HARD ACCEL FRCT: .11
CRUISING FRCT: .47
HARD DECEL FRCT: .10
IDLE FRCT: .32

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	15.1	.043					
IMEDIUM	14.3	.202					
ILONG	1.3	.073					
0-4 MPH			.016	.009	.005	.011	.011
5-9 MPH			.020	.014	.012	.016	.022
10-14 MPH			.019	.016	.014	.020	.020
15-19 MPH			.017	.018	.016	.024	.019
20-24 MPH			.013	.023	.025	.028	.016
25-29 MPH			.009	.024	.031	.031	.010
30-34 MPH			.004	.017	.028	.025	.005
35-39 MPH			.002	.009	.016	.014	.003
40-44 MPH			.001	.004	.006	.005	.001
45-49 MPH			.000	.002	.004	.003	.000
50-54 MPH			.000	.000	.001	.001	.000
>=55 MPH			0.000	.001	.001	.001	.000
TOTAL:	30.7	.318	.102	.137	.158	.177	.108

TRIP TYPE: TRANSIT - URBAN:WKDY-OFF - 30 TRIPS

TRIP DIST: 7.6 mi.
TRIP DUR: 29.5 min.
SERVICE STOPS: 15.1
TRIP SPEED: 15.4 mph
DRIVING SPEED: 21.8 mph

HARD ACCEL FRCT: .11
CRUISING FRCT: .49
HARD DECEL FRCT: .10
IDLE FRCT: .30

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	15.5	.041					
IMEDIUM	15.1	.201					
ILONG	1.2	.056					
0-4 MPH			.016	.009	.005	.012	.011
5-9 MPH			.020	.012	.011	.013	.022
10-14 MPH			.018	.017	.018	.020	.021
15-19 MPH			.017	.016	.016	.024	.018
20-24 MPH			.013	.020	.022	.026	.016
25-29 MPH			.009	.023	.030	.031	.011
30-34 MPH			.005	.019	.028	.025	.006
35-39 MPH			.002	.012	.020	.016	.003
40-44 MPH			.001	.005	.009	.007	.001
45-49 MPH			.000	.002	.004	.003	.001
50-54 MPH			.000	.001	.001	.001	.000
>=55 MPH			.000	.003	.006	.004	.000
TOTAL:	31.8	.298	.102	.140	.169	.181	.109

SUMMARY OF CHASE CAR DATA - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - URBAN:SAT - 12 TRIPS

TRIP DIST: 7.8 mi.
TRIP DUR: 30.0 min.
SERVICE STOPS: 15.7
TRIP SPEED: 15.7 mph
DRIVING SPEED: 22.2 mph

HARD ACCEL FRCT: .09
CRUISING FRCT: .54
HARD DECEL FRCT: .08
IDLE FRCT: .30

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	13.5	.039					
IMEDIUM	12.5	.166					
ILONG	1.8	.095					
0-4 MPH			.015	.009	.004	.011	.009
5-9 MPH			.018	.014	.007	.013	.020
10-14 MPH			.016	.018	.015	.021	.016
15-19 MPH			.013	.027	.022	.029	.015
20-24 MPH			.008	.029	.029	.031	.012
25-29 MPH			.005	.026	.033	.030	.007
30-34 MPH			.003	.020	.029	.024	.004
35-39 MPH			.001	.013	.020	.017	.001
40-44 MPH			.000	.005	.009	.007	.000
45-49 MPH			.000	.001	.002	.002	0.000
50-54 MPH			0.000	.002	.002	.001	0.000
>=55 MPH			0.000	.004	.007	.004	0.000
TOTAL:	27.8	.299	.080	.167	.179	.190	.085

TRIP TYPE: TRANSIT - URBAN:SUN - 12 TRIPS

TRIP DIST: 8.2 mi.
TRIP DUR: 30.0 min.
SERVICE STOPS: 13.7
TRIP SPEED: 16.6 mph
DRIVING SPEED: 23.4 mph

HARD ACCEL FRCT: .08
CRUISING FRCT: .54
HARD DECEL FRCT: .08
IDLE FRCT: .30

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	11.1	.032					
IMEDIUM	11.7	.166					
ILONG	1.8	.107					
0-4 MPH			.014	.009	.004	.010	.008
5-9 MPH			.015	.014	.008	.011	.016
10-14 MPH			.015	.017	.012	.017	.015
15-19 MPH			.012	.022	.018	.025	.013
20-24 MPH			.009	.030	.033	.030	.012
25-29 MPH			.006	.025	.032	.031	.007
30-34 MPH			.005	.022	.032	.028	.005
35-39 MPH			.002	.013	.023	.018	.002
40-44 MPH			.000	.006	.010	.007	.001
45-49 MPH			.000	.003	.004	.003	.000
50-54 MPH			0.000	.002	.003	.002	0.000
>=55 MPH			0.000	.004	.008	.005	0.000
TOTAL:	24.5	.305	.077	.166	.186	.187	.079

SUMMARY OF CHASE CAR DATA - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - SMALL URB:WKDY-PK - 20 TRIPS

TRIP DIST:	8.9 mi.	HARD ACCEL FRCT:	.09
TRIP DUR:	31.4 min.	CRUISING FRCT:	.51
SERVICE STOPS:	8.6	HARD DECEL FRCT:	.09
TRIP SPEED:	17.0 mph	IDLE FRCT:	.31
DRIVING SPEED:	24.4 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	14.2	.032					
IMEDIUM	10.1	.135					
ILONG	1.7	.145					
0-4 MPH			.014	.011	.006	.011	.009
5-9 MPH			.015	.016	.010	.014	.018
10-14 MPH			.014	.016	.012	.015	.015
15-19 MPH			.012	.015	.010	.018	.014
20-24 MPH			.010	.016	.015	.017	.013
25-29 MPH			.008	.023	.024	.027	.009
30-34 MPH			.005	.025	.031	.030	.006
35-39 MPH			.003	.018	.029	.024	.003
40-44 MPH			.001	.011	.019	.015	.001
45-49 MPH			.001	.006	.011	.007	.001
50-54 MPH			.000	.002	.004	.003	.000
>=55 MPH			.000	.001	.002	.002	.000
TOTAL:	26.0	.312	.084	.160	.172	.181	.090

TRIP TYPE: TRANSIT - SMALL URB:WKDY-OFF - 20 TRIPS

TRIP DIST:	9.4 mi.	HARD ACCEL FRCT:	.09
TRIP DUR:	31.9 min.	CRUISING FRCT:	.53
SERVICE STOPS:	8.4	HARD DECEL FRCT:	.09
TRIP SPEED:	17.8 mph	IDLE FRCT:	.29
DRIVING SPEED:	24.9 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	11.6	.025					
IMEDIUM	9.5	.128					
ILONG	1.4	.150					
0-4 MPH			.013	.008	.003	.007	.007
5-9 MPH			.015	.015	.010	.011	.018
10-14 MPH			.015	.016	.010	.015	.015
15-19 MPH			.013	.018	.014	.018	.015
20-24 MPH			.010	.019	.015	.019	.013
25-29 MPH			.008	.022	.025	.028	.009
30-34 MPH			.005	.023	.033	.028	.006
35-39 MPH			.003	.020	.031	.025	.003
40-44 MPH			.002	.013	.022	.016	.002
45-49 MPH			.001	.006	.010	.007	.001
50-54 MPH			.000	.003	.006	.004	.000
>=55 MPH			.000	.000	.001	.001	.000
TOTAL:	22.5	.303	.083	.165	.180	.180	.089

SUMMARY OF CHASE CAR DATA - 210 TRIPS TOTAL

TRIP TYPE: TRANSIT - SMALL URB:WKEND - 16 TRIPS

TRIP DIST: 8.0 mi.
TRIP DUR: 30.0 min.
SERVICE STOPS: 7.1
TRIP SPEED: 15.9 mph
DRIVING SPEED: 23.6 mph

HARD ACCEL FRCT: .09
CRUISING FRCT: .51
HARD DECEL FRCT: .08
IDLE FRCT: .33

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	11.2	.023					
IMEDIUM	8.8	.125					
ILONG	2.6	.178					
0-4 MPH			.014	.010	.003	.009	.008
5-9 MPH			.015	.018	.012	.012	.017
10-14 MPH			.015	.017	.012	.017	.016
15-19 MPH			.012	.018	.011	.018	.015
20-24 MPH			.010	.023	.018	.019	.014
25-29 MPH			.007	.025	.028	.030	.009
30-34 MPH			.004	.023	.033	.028	.005
35-39 MPH			.002	.015	.025	.019	.003
40-44 MPH			.001	.008	.016	.012	.001
45-49 MPH			.000	.004	.007	.005	.000
50-54 MPH			0.000	.002	.004	.002	0.000
>=55 MPH			0.000	.000	.001	.001	0.000
TOTAL:	22.6	.326	.080	.164	.171	.172	.088

TRIP TYPE: SCHOOL - URBAN:AM - 14 TRIPS

TRIP DIST: 8.2 mi.
TRIP DUR: 29.5 min.
SERVICE STOPS: 4.0
TRIP SPEED: 16.3 mph
DRIVING SPEED: 23.2 mph

HARD ACCEL FRCT: .11
CRUISING FRCT: .48
HARD DECEL FRCT: .10
IDLE FRCT: .31

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	10.8	.025					
IMEDIUM	9.8	.137					
ILONG	2.0	.141					
0-4 MPH			.014	.008	.005	.008	.008
5-9 MPH			.018	.011	.012	.011	.020
10-14 MPH			.019	.014	.014	.017	.019
15-19 MPH			.017	.015	.012	.017	.018
20-24 MPH			.013	.019	.022	.023	.016
25-29 MPH			.009	.023	.031	.027	.010
30-34 MPH			.006	.021	.036	.025	.007
35-39 MPH			.002	.013	.023	.018	.003
40-44 MPH			.001	.006	.011	.007	.001
45-49 MPH			.000	.002	.004	.002	.000
50-54 MPH			.001	.008	.011	.006	.000
>=55 MPH			.000	.002	.004	.004	.001
TOTAL:	22.6	.303	.099	.142	.186	.166	.104

SUMMARY OF CHASE CAR DATA - 210 TRIPS TOTAL

TRIP TYPE: SCHOOL - URBAN:PM - 14 TRIPS

TRIP DIST:	7.8 mi.	HARD ACCEL FRCT:	.10
TRIP DUR:	27.4 min.	CRUISING FRCT:	.50
SERVICE STOPS:	3.6	HARD DECEL FRCT:	.09
TRIP SPEED:	17.5 mph	IDLE FRCT:	.31
DRIVING SPEED:	24.0 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	10.8	.026					
IMEDIUM	8.4	.128					
ILONG	1.6	.155					
0-4 MPH			.012	.009	.005	.008	.007
5-9 MPH			.017	.014	.014	.012	.018
10-14 MPH			.016	.017	.015	.014	.017
15-19 MPH			.016	.014	.014	.018	.017
20-24 MPH			.012	.019	.020	.022	.015
25-29 MPH			.008	.020	.032	.027	.009
30-34 MPH			.004	.021	.029	.024	.005
35-39 MPH			.001	.013	.025	.016	.003
40-44 MPH			.000	.003	.006	.005	.001
45-49 MPH			.000	.003	.003	.002	.000
50-54 MPH			.000	.007	.008	.005	.000
>=55 MPH			.001	.010	.020	.013	.001
TOTAL:	20.8	.309	.088	.150	.191	.167	.094

TRIP TYPE: SCHOOL - SMALL URB:AM - 14 TRIPS

TRIP DIST:	7.3 mi.	HARD ACCEL FRCT:	.08
TRIP DUR:	25.6 min.	CRUISING FRCT:	.54
SERVICE STOPS:	6.0	HARD DECEL FRCT:	.07
TRIP SPEED:	16.4 mph	IDLE FRCT:	.31
DRIVING SPEED:	23.6 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	8.4	.018					
IMEDIUM	7.4	.145					
ILONG	1.4	.135					
0-4 MPH			.013	.012	.007	.011	.007
5-9 MPH			.016	.017	.012	.014	.017
10-14 MPH			.013	.022	.019	.019	.015
15-19 MPH			.012	.018	.013	.018	.014
20-24 MPH			.009	.020	.019	.020	.013
25-29 MPH			.006	.022	.028	.025	.006
30-34 MPH			.004	.020	.026	.025	.004
35-39 MPH			.002	.016	.024	.018	.003
40-44 MPH			.002	.011	.019	.014	.002
45-49 MPH			.001	.006	.009	.006	.001
50-54 MPH			.001	.007	.013	.008	.001
>=55 MPH			.000	.000	.001	.001	.000
TOTAL:	17.3	.298	.078	.171	.190	.180	.082

SUMMARY OF CHASE CAR DATA - 210 TRIPS TOTAL

TRIP TYPE: SCHOOL - SMALL URB:PM - 14 TRIPS

TRIP DIST:	7.6 mi.	HARD ACCEL FRCT:	.08
TRIP DUR:	25.9 min.	CRUISING FRCT:	.54
SERVICE STOPS:	7.0	HARD DECEL FRCT:	.07
TRIP SPEED:	17.0 mph	IDLE FRCT:	.31
DRIVING SPEED:	24.3 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	7.4	.019					
IMEDIUM	7.7	.121					
ILONG	1.4	.168					
0-4 MPH			.012	.012	.005	.010	.007
5-9 MPH			.013	.018	.012	.012	.016
10-14 MPH			.012	.022	.017	.020	.013
15-19 MPH			.011	.021	.016	.023	.012
20-24 MPH			.008	.019	.022	.022	.010
25-29 MPH			.006	.018	.024	.023	.007
30-34 MPH			.004	.017	.025	.022	.004
35-39 MPH			.002	.014	.019	.015	.003
40-44 MPH			.001	.009	.014	.010	.001
45-49 MPH			.000	.009	.016	.008	.001
50-54 MPH			.000	.007	.011	.008	.000
>=55 MPH			.000	.006	.012	.008	.000
TOTAL:	16.6	.308	.069	.174	.193	.182	.074

TRIP TYPE: SCHOOL - RURAL:AM - 7 TRIPS

TRIP DIST:	11.7 mi.	HARD ACCEL FRCT:	.09
TRIP DUR:	25.4 min.	CRUISING FRCT:	.62
SERVICE STOPS:	6.7	HARD DECEL FRCT:	.09
TRIP SPEED:	27.1 mph	IDLE FRCT:	.19
DRIVING SPEED:	32.7 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	5.1	.014					
IMEDIUM	6.9	.113					
ILONG	.6	.057					
0-4 MPH			.009	.004	.003	.005	.005
5-9 MPH			.014	.009	.011	.010	.013
10-14 MPH			.012	.009	.008	.010	.014
15-19 MPH			.012	.007	.006	.012	.013
20-24 MPH			.011	.010	.014	.013	.013
25-29 MPH			.010	.016	.023	.018	.011
30-34 MPH			.008	.014	.021	.019	.009
35-39 MPH			.007	.016	.029	.022	.006
40-44 MPH			.005	.018	.033	.026	.005
45-49 MPH			.004	.021	.037	.024	.002
50-54 MPH			.002	.025	.046	.026	.002
>=55 MPH			.001	.013	.033	.021	.001
TOTAL:	12.6	.184	.093	.162	.263	.205	.093

SUMMARY OF CHASE CAR DATA - 210 TRIPS TOTAL

TRIP TYPE: SCHOOL - RURAL:PM - 7 TRIPS

TRIP DIST:	10.4 mi.	HARD ACCEL FRCT:	.10
TRIP DUR:	28.0 min.	CRUISING FRCT:	.58
SERVICE STOPS:	9.6	HARD DECEL FRCT:	.10
TRIP SPEED:	22.6 mph	IDLE FRCT:	.22
DRIVING SPEED:	28.9 mph		

SPEED/IDLE	# IDLE EVENTS	IDLE (Frct.)	FRACTION OF TIME SPENT IN EACH ACCELERATION RANGE <=-2	>-2,<=-.25	>-.25,<.25	>=.25,<2	>=2 mph/s
ISHORT	8.7	.021					
IMEDIUM	8.6	.135					
ILONG	.9	.075					
0-4 MPH			.011	.006	.004	.006	.007
5-9 MPH			.016	.010	.010	.011	.018
10-14 MPH			.015	.011	.011	.012	.015
15-19 MPH			.013	.011	.010	.018	.014
20-24 MPH			.013	.015	.022	.022	.014
25-29 MPH			.010	.018	.026	.028	.009
30-34 MPH			.007	.018	.031	.026	.007
35-39 MPH			.005	.014	.022	.022	.004
40-44 MPH			.004	.017	.031	.022	.003
45-49 MPH			.002	.012	.023	.017	.002
50-54 MPH			.001	.012	.021	.013	.001
>=55 MPH			.000	.006	.010	.008	.001
TOTAL:	18.1	.231	.098	.151	.219	.204	.096